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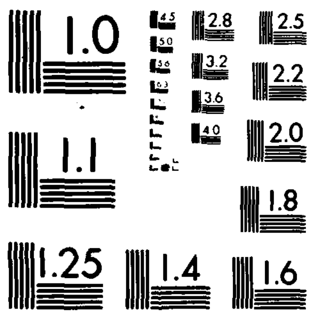

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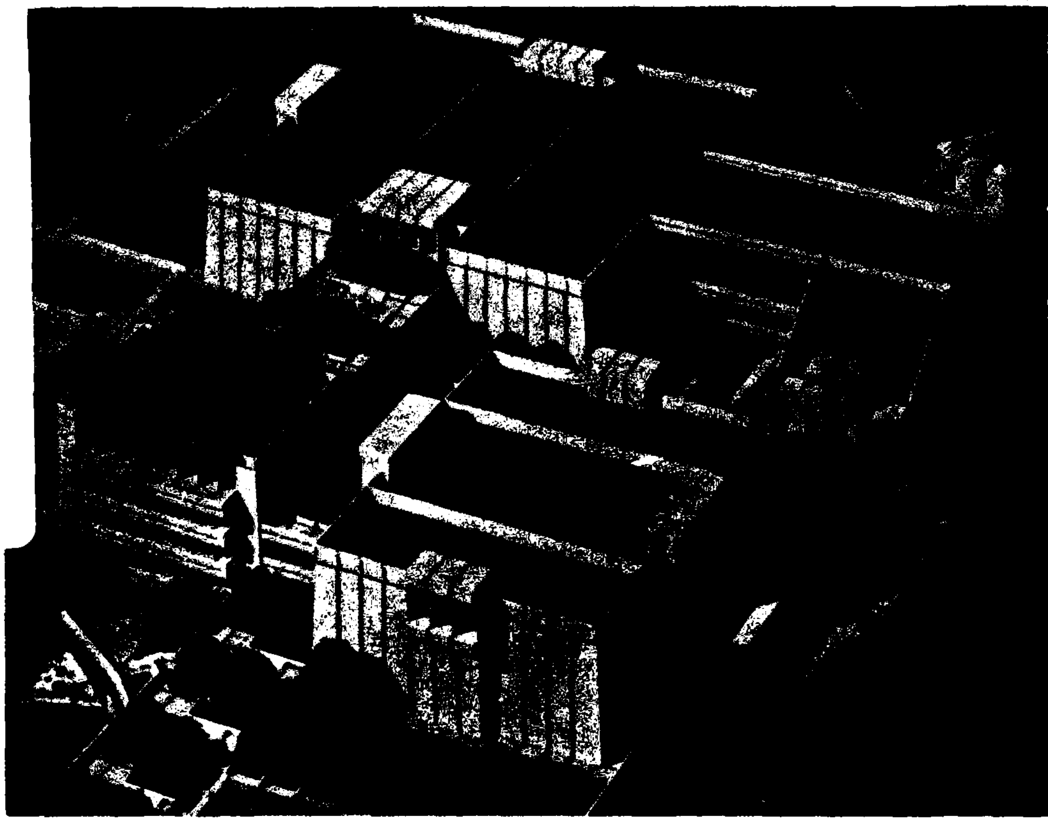
COMPUTERIZED METHOD FOR THE GENERATION OF MOLECULAR TRANSMITTANCE FUNCTIONS IN THE INFRARED REGION

FINAL REPORT



ENGINEERING AND SCIENCE COMPLEX

The University of Texas at El Paso

COMPUTERIZED METHOD FOR THE GENERATION

OF MOLECULAR TRANSMITTANCE FUNCTIONS

IN THE INFRARED REGION

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FINAL REPORT 12/31/79 FR1-79-UA-72

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study is made of two basically distinct methods normally used in the development of band models for the calculation of gaseous molecular transmittance in the infrared region. The first method consists of the determination of the "empirical" transmittance function and the associated absorber and spectral parameters from measured or calculated transmittance spectra. The second method consists of the determination of the absorber and spectral parameters → over

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with an assumed "analytical" transmittance function, using the same type of data. Computerized numerical techniques are presented in connection with the first method and a generalized transmittance function is adopted for the second method. Although the methodology is generally applicable to other gaseous species, it is specifically discussed in connection with the trace gases SO_2, NO, NO_2, and NH_3. As a secondary effort a structural breakdown of the Lowtran code is presented for the purpose of incorporating the band models for the trace gases. The code is separated into basic functional modules or subroutines controlled by a main program. The modularization itself was primarily performed under a separate effort through the Atmospheric Sciences Laboratory.

ABSTRACT

A study is made of two basically distinct methods normally used in the development of band models for the calculation of gaseous molecular transmittance in the infrared region. The first method consists of the determination of the "empirical" transmittance function and the associated absorber and spectral parameters from measured or calculated transmittance spectra. The second method consists of the determination of the absorber and spectral parameters with an assumed "analytical" transmittance function, using the same type of data. Computerized numerical techniques are presented in connection with the first method and a generalized transmittance function is adopted for the second method. Although the methodology is generally applicable to other gaseous species, it is specifically discussed in connection with the trace gases SO_2, NO, NO_2 and NH_3. As a secondary effort a structural breakdown of the Lowtran code is presented for the purpose of incorporating the band models for the trace gases. The code is separated into basic functional modules or subroutines controlled by a main program. The modularization itself was primarily performed under a separate effort through the Atmospheric Sciences Laboratory.

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I. Introduction

Following the efforts of Elssaser[1] numerous workers have attempted to arrive at computationally-simple models for gaseous molecular transmittance, averaged over narrow spectral intervals in the infrared. These efforts may be naturally divided into those involving the analytical derivation of a mean transmittance function from Beer's Law, and those involving the extraction of the transmittance function itself from transmittance data. Traditionally, the former are called "analytical" and the latter are called "empirical". The method normally used in the empirical models consists of the extraction of the transmittance function through graphical techniques, with the adoption of a relationship between spectral and absorber parameters. In the development of analytical models a transmittance function is adopted at the offset, and the spectral and absorber parameters are afterward determined through computerized numerical procedures.

In the work reported here the authors present a totally computerized version of the classical graphical methods for the extraction of the empirical transmittance function. This is followed by a presentation of a numerical method which uses a double-exponential transmittance function for the development of analytical band models. Both methods are then applied to 20 cm^{-1} averaged line-by-line

transmittance data for the atmospheric trace gases SO_2, NO, NO_2, and NH_3. The model parameters are listed at 5 cm^{-1} intervals throughout the major absorption bands of these gases for the convenience of the community of band model users. Although the methodology is applied specifically to the trace gases, no restrictions are immediately evident in the extension to other gaseous absorbers in the infrared. In fact, the analytical method was successfully applied earlier[2] to the principal band centers of the major absorbers H_2O vapor, O_3 and the uniformly-mixed gases.

As an application of the results found through this effort, the band models for the trace gases were incorporated in the widely-used code called Lowtran. To facilitate the inclusion of these models, as well as of others, the code was broken down into separate subroutines or modules controlled by a master program. The subroutines include the evaluation of the equivalent absorber amount, the selection of the spectrally-effective attenuation model and the individual attenuation models. The principal purpose of the modularization is to assist users with the modification of the code to suit their individual requirements on transmission models.

II. The Transmittance Equation

The monochromatic transmittance τ_ν at frequency ν for the passage of infrared radiation through a path length Z in an inhomogeneous medium with pressure and temperature distributions P(Z) and T(Z), respectively, is given by Beer's Law in the form

$$\tau_\nu = e^{-\int K_\nu(P,T)\,dU(Z)} \tag{1}$$

where K_ν is the resultant absorption coefficient for all contributing lines and gaseous absorbers, and U is the absorber amount. For broadband radiation detected by an instrument of spectral response ϕ_ν, the variable of interest is the weighted mean transmittance τ, defined as

$$\tau = \int \tau_\nu \phi_\nu d\nu \Big/ \int \phi_\nu d\nu \tag{2}$$

Equation (2) has been evaluated analytically over a spectral interval $\Delta\nu$ for the special case of Lorentzian broadened lines having assumed line distributions and intensities, leading to the classical band models[1,3]. Numerous variations of the classical band models may be found in the literature, most of which specify the analytical form of τ in terms of mean line or meteorological variables. A notable exception is the model of King[4] which expresses the homogeneous-path transmittance as

$$\tau = g(S\alpha^n U), \tag{3}$$

where g is a function to be determined empirically, S is the mean line intensity, α is the mean line half-width and n is an absorber parameter with the physical constraints of zero and one in the weak-line and strong-line limits, respectively. The path inhomogeneity may be accounted for in Eq. (3) through the Curtis-Godson equivalences

$$S\alpha^n U = \int S(Z)\alpha^n(Z)dU(Z). \qquad (4)$$

From practical considerations, it is often desirable to transform the argument in Eq.(3) with the known relations

$$S = S_o \left(\frac{T_o}{T}\right)^a \qquad (5)$$

$$\alpha = \alpha_o \left(\frac{P}{P_o}\right)\left(\frac{T_o}{T}\right)^{1/2} \qquad (6)$$

in order to obtain

$$\tau = g \left\{ C\left(\frac{P}{P_o}\right)^n \left(\frac{T_o}{T}\right)^m U \right\}, \qquad (7)$$

where C is a spectral parameter combining S_o and α_o^n, m is an absorber parameter combining the temperature exponents of S and α, a is an absorber constant, and the subscript "o" denotes standard conditions. For computational convenience Eq. (7) may be expressed as

$$\tau = f\{x\}, \qquad (8)$$

where

$$x = C' + \log_{10} W \tag{9}$$

$$C' = \log_{10} C \tag{10}$$

$$W = \left(\frac{P}{P_o}\right)^n \left(\frac{T_o}{T}\right)^m U \quad . \tag{11}$$

Here, f is the transmittance function, C' is the spectral parameter, W is the equivalent absorber amount, and n and m are the absorber parameters; all of which are to be determined from transmittance data for each absorber.

III. Computerized Method of Empirical Model Development

3.1 Introduction

Assuming the availability of equal transmittance data, which is defined below, we have developed an algorithm, called ADSET, which evaluates absorber parameters n, m, spectral parameters $C'(\nu)$ and an empirical transmission function simultaneously. In the algorithm the transmission function is linearized and a linear regression technique is utilized for parameter evaluation. In order to evaluate the band model parameters and the empirical transmission function simultaneously, a set of auxiliary variables are introduced. Each data point is identified through the auxiliary variables to an absorption band and to a transmittance 'cut'. This enables us to obtain globally optimal set of parameters and the empirical transmission function simultaneously.

Based on the derived optimal pointwise transmission function, a piecewise analytical transmission function is developed. The commonly used computer code Lowtran for the evaluation of atmospheric transmittance can be greatly simplified by the use of this piecewise analytical transmission function to model the major absorbers.

Finally, the code ADSET also contains a subroutine which can compute the spectral parameter value $C'(\nu)$ for non-major absorption bands.

3.2 Data Structure

Several transmittance values τ_j, j=1, 2, ..., NCUT are chosen a priori, where NCUT is the number of chosen transmittance values. Curves of growth data (i.e. τ versus U) for each layer of atmosphere are assumed to be given at these transmittance values. Therefore, the curves of growth have 'cut' structure, namely, all data points are on one of the transmittance cuts $\tau = \tau_j$, j=1, 2, ..., NCUT (See Fig. 1). We call a data set with this cut structure an 'equal transmittance' data in the sequel.

3.3 Linearization of Transmission Function

Since f in Eq.(8) is known to be strictly monotone decreasing from one to zero as x changes from $-\infty$ to ∞, there exists an inverse function f^{-1} defined on (0,1) such that

$$\begin{aligned} x &= f^{-1}(\tau) \\ &= C' + \log W \\ &= C' + n\log(\frac{P}{P_o}) + m\log(\frac{T_o}{T}) + \log U. \qquad (12) \end{aligned}$$

Let us define x_j, j=1, 2, ..., NCUT be the inverse image of the prechosen transmittance values τ_j, j=1, 2, ..., NCUT i.e.,

$$x_j = f^{-1}(\tau_j), \quad j= 1, 2, \ldots, NCUT. \qquad (13)$$

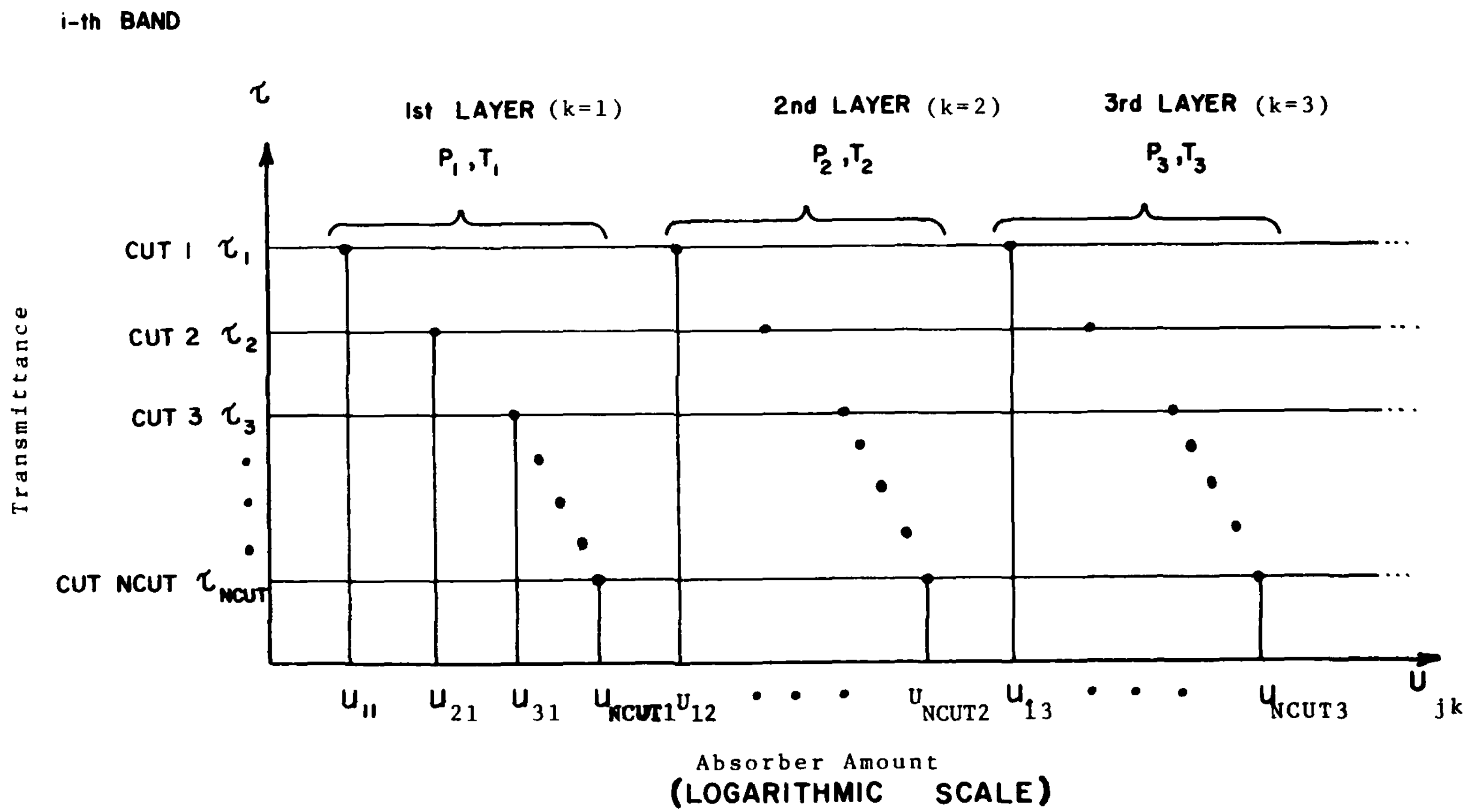

Fig. 1. Schematic representation of "equal transmittance" data structure.

Then, the set of points (x_j, τ_j), $j = 1, 2, \ldots$, NCUT is nothing but the empirical transmission function, which is to be found. From Eq. (12), we reach the following regression equation.

$$n \log(\frac{P}{P_o}) + m \log(\frac{T_o}{T}) + C' - x = -\log U. \qquad (14)$$

Note that this equation is linear in the unknown parameters n, m, C' and x. Therefore, the linear regression technique can be used to evaluate the optimum values for the parameters.

3.4 Formation of the Square Error

The square error corresponding to the k-th data point in i-th absorption band's j-th cut, denoted by E_{ijk}, is given by

$$E_{ijk} = \{n\log(\frac{P_{ijk}}{P_o}) + m\log(\frac{T_o}{T_{ijk}}) + C_i' - x_j - (-\log U_{ijk})\}^2 \qquad (15)$$

Hence, the total square error E_{ij} for this cut is

$$E_{ij} = \sum_{k=1}^{L_{ij}} E_{ijk}, \qquad (16)$$

where L_{ij} is the number of layers in this cut. Similarly, the total square error E_i for i-th band and the grand total square error E are given by

$$E_i = \sum_{j=1}^{J_i} E_{ij} = \sum_{j=1}^{J_i} \sum_{k=1}^{L_{ij}} E_{ijk}, \qquad (17)$$

$$E = \sum_{i=1}^{NB} E_i = \sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_{ij}} E_{ijk}, \qquad (18)$$

where J_i and NB are the numbers of the cuts in i-th absorption band and of the absorption bands, respectively. The final expression can be simplified if we assume that the number of layers (L_{ij}) in every cut is equal to a constant L_i. For this case

$$E = \sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_i} E_{ijk}. \qquad (19)$$

Our objective is to find optimum set of parameters (n^*, m^*, $C'_1{}^*$, $C'_2{}^*$, ..., $C'_{NB}{}^*$, $x_1{}^*$, $x_2{}^*$, ..., $x_{NCUT}{}^*$) which minimizes this grand total error E.

3.5 Auxiliary Variables

In order to perform the minimization of E with respect to the above parameters simultaneously, we modify the square error E_{ijk} so that it contains all the parameters. This is done by introducing two sets of auxiliary variables u_i, i=1, 2, ..., NB and v_j, j=1, 2, ..., NCUT. Using them, E_{ijk} is redefined as

$$E_{ijk} = \{n\log(\frac{P_{ijk}}{P_o}) + m\log(\frac{T_o}{T_{ijk}}) + u_{1,ijk} C'_1 + \dots + u_{NB,ijk} C'_{NB} + v_{1,ijk} K_1 + \dots + v_{NCUT,ijk} K_{NCUT} - (-\log U_{ijk})\}^2 \qquad (20)$$

where $K_j = -x_j$, $j=1, 2, \ldots, NCUT$. The auxiliary variables act as identifiers of the band and the cut. If a data point is for $\hat{i}$-th band's $\hat{j}$-th cut, then $u_{\hat{i}} = 1$ and $u_i = 0$ for all $i \neq \hat{i}$ and $v_{\hat{j}} = 1$ and $v_j = 0$ for all $j \neq \hat{j}$. Thus, only the spectral parameter $C'_{\hat{j}}$ and the cut parameter $K_{\hat{j}}$ corresponding to the current data are active and all other spectral and cut parameters disappear. Hence, Eq. (20) reduces to Eq. (15). The change from x_j to $K_j = -x_j$ is made in order to symmetrize the coefficient matrix of the resulting normal equation. This change makes it possible to utilize any specialized solution method for the symmetric normal equation when the space conservation is important.

3.6 Regression Analysis

Using the grand total error E with the redefined E_{ijk} in Eq. (20), the best parameter values n^*, m^*, C'^*_1, ..., C'^*_{NB}, K^*_1, ..., K^*_{NCUT} are simultaneously determined by the linear regression. Setting the partial derivatives of E with respect to parameters equal to zero results in a linear normal equation of the form $AX = B$, where A, B and X are, respectively, a symmetric coefficient matrix, a constant vector and a parameter vector defined by

$$A = \left[\begin{array}{c|c|c} \begin{matrix}\Sigma v^2_{NCUT} & & 0\\ & \ddots & \\ 0 & & \Sigma v^2_1\end{matrix} & * & * \\ \hline * & \begin{matrix}\Sigma u^2_{NB} & & 0 \\ & \ddots & \\ 0 & & \Sigma u^2_2\end{matrix} & * \\ \hline * & * & \begin{matrix}\Sigma(\log\frac{T}{T_o})^2 & * \\ * & \Sigma(\log\frac{P}{P_o})^2\end{matrix}\end{array}\right] \qquad (21)$$

$$B = \Big[\Sigma(-v_{NCUT}\ \log U),\ \ldots,\ \Sigma(-v_1 \log U),\ \Sigma(-u_{NB} \log U),\ \ldots,$$

$$\Sigma(-u_2 \log U),\ \Sigma(-\log(\frac{T_o}{T})\log U),\ \Sigma(-\log(\frac{P}{P_o})\log U)\Big]^t, \quad (22)$$

$$X = \Big[K_{NCUT},\ \ldots,\ K_1,\ C'_{NB},\ \ldots,\ C'_2,\ m,n\Big]^t \quad (23)$$

The * in Eq. (21) represents some nonzero elements. Also the Σ in the above equations represents the triple sum $\sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_i}$ in Eq. (19). One may realize that C'_1 does not appear in Eq. (23) and hence the corresponding auxiliary variable u_1 is also absent from Eqs. (21) and (22). This is because one of C'_1, ..., C'_{NB} is dependent on other C'_i so that C'_1, ..., C'_{NB} cannot be determined uniquely. It is necessary that one of C'_is be given a number *a priori*. Here C'_1 is chosen and is given the value zero, and therefore is eliminated from the parameter vector X. This choice calls for some explanation. On τ vs. logW diagram the optimum empirical transmission function can be placed anywhere. What it amounts to is that a different placement results in a different set of C'_i values which is a linear shift (addition or subtraction of a constant) of another set of C'_i values. Only the relative relationship among C'_i is unique. This is clearly indicated in Fig. 2.

Since the placement of the empirical transmission function is arbitrary, we may position it on the data points corresponding to the first absorption band. In other words, the first absorption band is taken as the

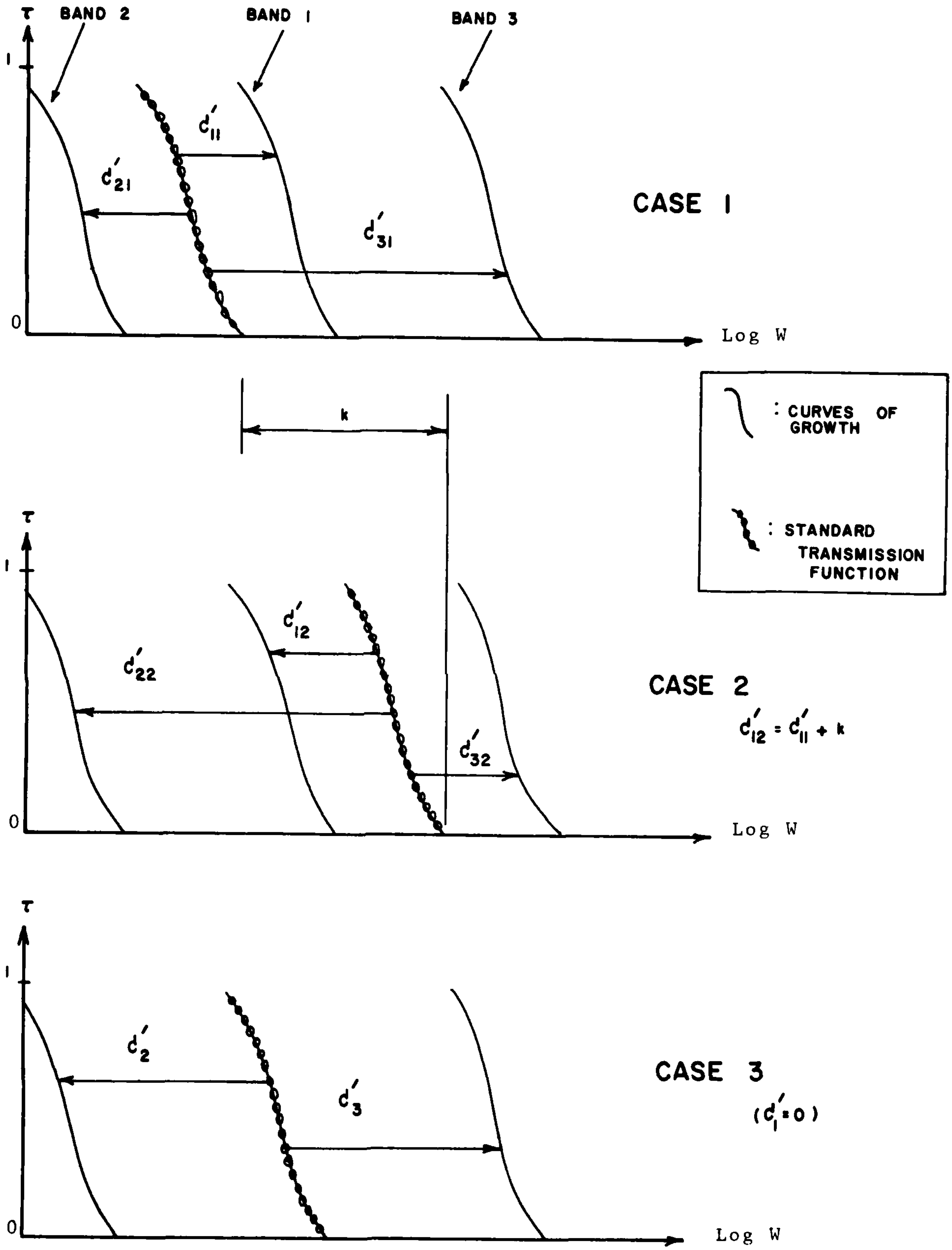

Fig. 2. Schematic representation of linear shift accounting for spectral dependence of transmittance.

reference band and the corresponding spectral parameter C_1' is set to be zero.

The queuing of parameters in X vector is determined in such a way that as many upper principal minor matrices as possible become diagonal (See Eq. (21)). This arrangement can reduce the amount of computation in the early stage of Gauss elimination steps when the normal equation is solved, and can result in less computational error.

3.7 Piecewise Analytical Transmission Function

After the best parameter values are computed, the piecewise analytical transmission function is generated by the piecewise interpolation. The transmittance region (0,1) is divided into NCUT - 1 subregions by the transmittance cuts $\tau_2, \tau_3, \ldots, \tau_{NCUT-1}$. Let $\tau_1 > \tau_2 > \ldots > \tau_{NCUT}$, then the subregions are given by

Subregion 1	$[\tau_2, 1)$,
Subregion 2	$[\tau_3, \tau_1]$,
.	.
.	.
.	.
Subregion NCUT-2	$[\tau_{NCUT-1}, \tau_{NCUT-2}]$,
Subregion NCUT-1	$(0, \tau_{NCUT-1}]$.

The top and bottom subregions contain τ_1 and τ_{NCUT} as an inner point, respectively. The interpolation in each

subregion is done by the double exponential function defined by

$$\tau(x) = \exp \{-10^{a_1 + a_2 x + a_3 x^2}\} . \qquad (24)$$

The generally-used linear interpolation is not used here since subregions cannot be assumed small enough for the linear approximation to be valid. Furthermore, the linear interpolation is totally inadequate for the top and bottom subregions. On the other hand, the double exponential function takes the values between and is asymptotic to one and zero as the argument varies from $-\infty$ to ∞. It is also known that this function closely approximates the standard empirical transmission function used in the Lowtran code.[2,16]

The parameters a_1, a_2, and a_3 for each subregion are determined by two different methods. The first method assumes that $a_3 = 0$ and uses no further data to compute a_1 and a_2. They are simply determined by the condition that the interpolation function in each subregion passes through the end points. In the top and bottom subregions, the function is required to pass through two points; (τ_1, x_1) and (τ_2, x_2) for the top and $(\tau_{NCUT-1}, x_{NCUT-1})$ and (τ_{NCUT}, x_{NCUT}) for the bottom subregions.

The second method does not assume that $a_3 = 0$ and requires additional data to compute parameter values. The same condition that each interpolation function passes

through two points reduces the number of unknown parameters to one. The last parameter is determined by minimizing the subregional square error E_i defined by

$$E_i = \sum_{i=1}^{L_i} \left(\tau_i - \exp\{-10^{a_1 = a_2 x_i + a_3 x_i^2}\}\right)^2 \qquad (25)$$

for those data points in respective subregions.

3.8 C' for Non-major Bands

Finally, the spectral parameters C' for non-major bands are computed by a straightforward method. The discrepancies between x^*_i and $\log W_i$ values computed for all cuts for one band are averaged to obtain the spectral parameter $C'(\nu)$ for that band, i.e.,

$$C' = \frac{1}{N} \sum_{i=1}^{N} (x_i^* - \log W_i), \qquad (26)$$

where W_i are computed by Eq. (11) with optimal n^* and m^*.

IV. Computerized Method of Analytical Model Development

4.1 Introduction

In the last chapter, we assumed no analytical form for the transmission function $\tau = f(x)$ when the standard transmission function was computed. Here, by assuming the double exponential form given by Eq. (24) as the transmission function for the entire transmittance range, we derive an algorithm which can evaluate the best function parameter values a_1, a_2, and a_3; together with the band model parameters n, m, and C_i'. Note that the double exponential function was used for the piecewise interpolation in the last chapter. But the computation of the function parameters was performed after the band model parameters and the empirical transmission function were obtained. In other words, the computation in the last chapter was sequential but not simultaneous. The algorithm we present in this chapter is, on the contrary, the simultaneous evaluation of all parameters. The preliminary development of this algorithm can be found in Ref. 5.

4.2 Basic Equations

The basic equations are Eq. (8) and Eq. (24) of the last chapter, which are cited here for the ease of reference.

$$\tau = f(x) \tag{27}$$

$$f(x) = \exp\{-10^{a_1 + a_2 x + a_3 x^2}\}. \tag{28}$$

Now, since we have assumed the function form, we can compute the transmittance if we have the value of x. Hence, we do not have to take the inverse function as we did before to perform the regression analysis. Instead, we take the square difference of the given and computed τ directly from this expression. Thus, we get

$$E_{ij} = [\tau_{ij} - \exp\{-10^{a_1+a_2x_{ij}+a_3x_{ij}^2}\}]^2 , \tag{29}$$

for i-th absorption band's j-th data point, where, as before, x_{ij} is given by

$$x_{ij} = C_i' + n \log(\frac{P_{ij}}{P_o}) + m \log(\frac{T_o}{T_{ij}}) + \log U_{ij}. \tag{30}$$

By summing this individual error for all data in i-th band, we have the total error for this band as

$$E_i = \sum_{j=1}^{J_i} E_{ij}, \tag{31}$$

where J_i is the number of data in i-th band.

Again, we introduce auxiliary variables u_i, i=1,2, ...,NB in order to introduce all C_i', i=1,2,...,NB into the x_{ij} expression Eq.(30). By this we get

$$x_{ij} = \sum_{k=1}^{NB} u_{k,ij}C'_k + n \log(\frac{P_{ij}}{P_o}) + m \log(\frac{T_o}{T_{ij}}) + \log U_{ij}, \tag{32}$$

We use this expression for x_{ij} in the following total error E

$$E = \sum_{i=1}^{NB} E_i = \sum_{i=1}^{NB} \sum_{j=1}^{J_i} E_{ij}. \tag{33}$$

Now, we are ready to take partial derivatives with respect to the parameters n, m, C_1', ..., C_{NB}', a_1, a_2, and a_3 to form the normal equation for this regression problem. Theoretically speaking, we can evaluate the 'best' parameter values by solving the normal equation. But obviously the grand total Eq. (33), which is to be minimized, is not a quadratic function of the unknown parameters and, therefore, the resulting normal equation is not a linear function of them. Hence, we need to adopt a different numerical method for the evaluation of the 'optimal' parameter values.

4.3 Nonlinear Optimization Method

The computational technique we use here is a recursive technique which is referred to as the conjugate gradient method[17]. In essence, this technique improves a set of guesses of the parameter values recursively by locating a new set of guesses which yields smaller error. For a given guess $(\alpha^n, \beta^n, \ldots, \gamma^n)$ of the minimizing parameter vector, at which the error is minimized, the best direction of the search in the parameter space for a new guess is first determined using up to second order derivatives of the error. Then the one-dimensional search for the minimizing point is performed along this direction from $(\alpha^n, \beta^n, \ldots, \gamma^n)$ to find a new guess $(\alpha^{n+1}, \beta^{n+1}, \ldots, \gamma^{n+1})$

which yields locally the smallest error. Now this procedure is repeated recursively to obtain a sequence of guesses until the gradients become less than a small positive number which is chosen *a priori*.

Actual computation was done by utilizing the packaged subroutine FMCG in SSP library available from IBM[18]. The necessary gradients are

$$
\begin{aligned}
\frac{\partial J}{\partial a_1} &= -2\Sigma D_j \delta f_j, \\
\frac{\partial J}{\partial a_2} &= -2\Sigma D_j \delta f_j x_j, \\
\frac{\partial J}{\partial a_3} &= -2\Sigma D_j \delta f_j x_j^{\;2}, \\
\frac{\partial J}{\partial n} &= -2\Sigma D_j \delta f_j (a_2 + 2a_3 x_j)\log(\frac{P_j}{P_o}), \\
\frac{\partial J}{\partial m} &= -2\Sigma D_j \delta f_j (a_2 + 2a_3 x_j)\log(\frac{T_o}{T_j}), \\
\frac{\partial J}{\partial C'_i} &= -2\Sigma D_j \delta f_j (a_2 + 2a_3 x_j) u_i,
\end{aligned}
\qquad (34)
$$

where, Σ represents $\sum_{i=1}^{NB} \sum_{j=1}^{J_i}$ and D_j and δf_j are given by

$$D_j = \{E_{ij}\}^{\frac{1}{2}}, \qquad (35)$$

$$\delta f_j = (\ln 10)\, 10^{a_1 + a_2 x_j + a_3 x_j^2} f(x_j), \qquad (36)$$

and f(x) is given by Eq. (28).

Note that there exists a linear dependence among the gradients which is

$$a_2 \frac{\partial J}{\partial a_1} + 2a_3 \frac{\partial J}{\partial a_2} = \sum_{i=1}^{NB} \frac{\partial J}{\partial C_i'} \qquad (37)$$

Therefore, the parameter set $\{n, m, C_1', \ldots, C_{NB}', a_1, a_2, a_3\}$ cannot be determined uniquely. As it was explained in the previous section, this is due to the arbitrariness in the positioning of the standard transmission function. Hence, the spectral parameter C_1' is again set to be zero, so that we can evaluate unique set of optimal parameters.

V. Comparison of the Two Methods

5.1 Introduction

Both methods can evaluate the optimal n, m and $C'(\nu)$ values for major and non-major bands and also a standard transmission function. But there are some basic differences which are discussed in the sequel.

5.2 Final Products

The final product of the ADSET code is a piecewise analytical standard transmission function together with the band model parameters. Each analytical piece of the standard transmission function covers only one of the pre-chosen subintervals of (0,1) transmittance range. On the other hand, SIMMIN produces only one analytical transmission curve for the entire range. Therefore, ADSET has more flexibility to adjust to the transmittance curve variations. This feature of ADSET can be very valuable for the gases with non-standard curves of growth.

This difference is amplified when the number of the transmittance sub-regions used in ADSET is increased. However, as the number of subregions increase, the requirement on the usable data becomes severer and more spaces are necessary to store the computed results. Hence, the determination of the number of subregions should be resorted to compromise.

5.3 Installation of the Results in Lowtran

The final products of two codes ADSET and SIMMIN were installed in the widely-used Lowtran code, as discussed in Section VII of this report. The SIMMIN results require less memory space, less time for transmittance computation and simpler coding than the ADSET result. In fact, for the SIMMIN result, all that have to be stored are the five band model parameters n, m, a_1, a_2, and a_3, and a set of spectral parameters $C'(\nu_i)$ for each absorber. Furthermore, the computation of τ can be done by only one FORTRAN statement. On the other hand, the ADSET result requires the storage of NCUT-1 of a_1, a_2, and a_3 values, n and m and a set of $C'(\nu)$ values for each absorber. There can be a large difference in the number of the sets of a_1, a_2, and a_3 values to be stored. Moreover, some judging statements are necessary to select the right set of a_1, a_2, and a_3 for each transmittance computation.

5.4 Data Requirements

The ADSET code requires the cut structured data such that the transmittance of each data point must fall in one of prechosen values. But the SIMMIN code does not impose any conditions on the data set.

Some considerations on the requirement of equal transmittance data for ADSET are due here. Even if the available data do not have equal transmittance structure,

it can be transformed into the required form using interpolation/extrapolation. This constitutes the pre-processing of the raw data. Curves of growth data τ vs. log U with τ values not necessarily coinciding with the prechosen values can be locally interpolated/extrapolated using an analytical function. This procedure is indicated in Fig. 3. Again, the double exponential function is an excellent choice for the interpolation function. We note that an almost exact technique as the one used in obtaining a piecewise analytical transmission function can be used for this purpose. In fact, only a minor modification of the interpolation subroutine used in ADSET can accomplish this task.

5.5 Computation Time

The numerical methods used in ADSET and SIMMIN for solving normal equations are essentially different. The method in SIMMIN is a recursive algorithm and the other in ADSET is a non-iterative one. Therefore, the computation time for ADSET is determined by the size of the data set only, whereas, the one for SIMMIN depends on both the actual data values and the initial guesses. It is difficult to estimate the computation time for SIMMIN due to this dependence. One way of controlling the time is to limit the number of iterations performed. This feature is included in the packaged subroutine FMCG which is used for actual

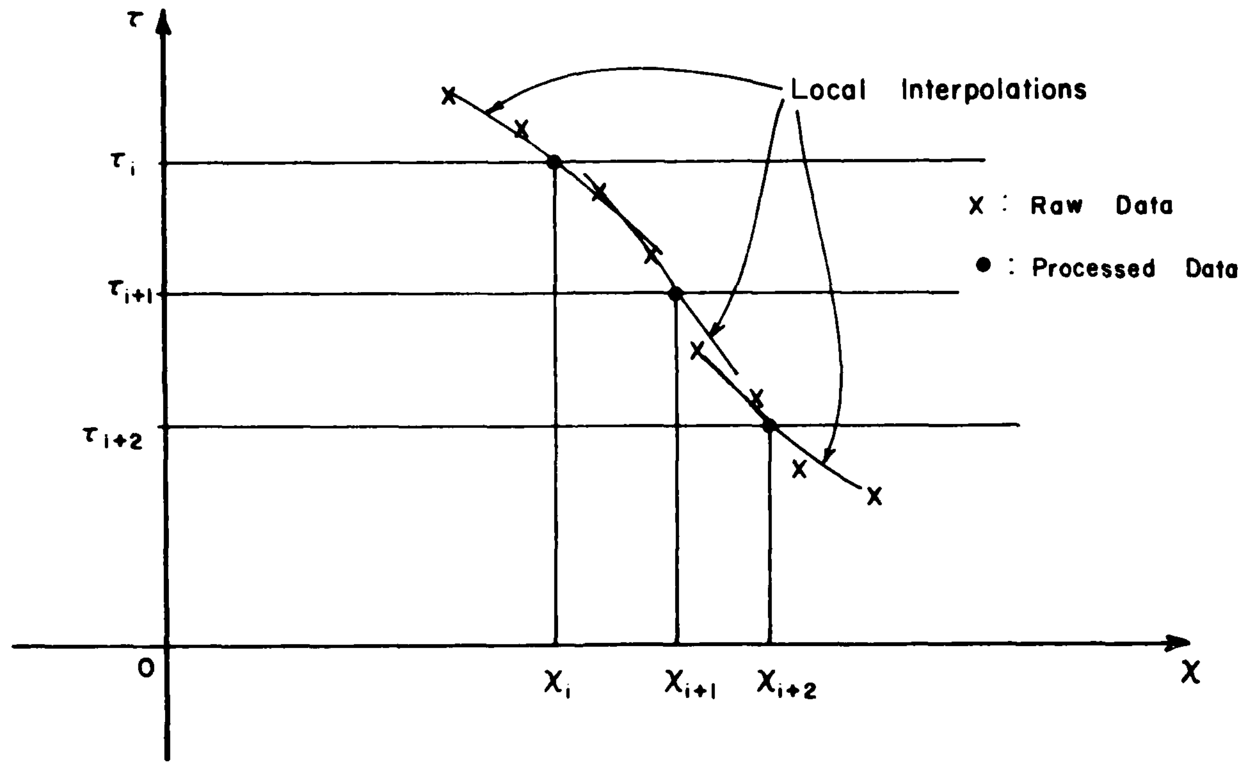

Fig. 3. Pre-processing of Data (τ_j, x_j), and the derived equal transmission data.

computations. Actual time ranges required for ADSET and SIMMIN computations will be given in a later section.

VI. Lowtran Capabilities and Functions

6.1 Introduction

The Lowtran code consists of a computer model for the calculation of transmittance through atmospheres containing absorbing and scattering molecules and aerosols. The models used in the code were for the most part developed in 1972[6] but later editions incorporated computational changes and other capabilities[7-10]. It covers the spectral range from 0.25 to 28.5 μm at intervals of 5 cm^{-1} with a resolution for the major absorbers of 20 cm^{-1}. The transmittance calculation is made on six model atmospheres and two haze models on a 33-level basis for altitude, pressure, temperature and density from sea-level to 100 km. The path of the transmission is considered to be refracted by changes in atmospheric density, a fact taken into account in an optional subroutine. In its present form the Lowtran code consists of a single main program that inputs the path data and model parameters, computes the equivalent absorber amount, and performs the transmittance calculations. The only present subroutines are associated with the path, and are optional. The difficulties of understanding and, especially, updating such a program structure are considerable.

The principal objective of this effort is to modify the program structure of the Lowtran code in accordance

with the following criteria:

1. The basic functions, calculations and printouts remain nearly identical to the original.

2. The basic operations involving the reading of data, the calculation of the equivalent path and the transmittance calculations are all separate, independent programs, but are connected as subroutines to a main control program.

3. The structure modification is performed on the latest version of the code, i.e., Lowtran 4.

As an exercise in the use of the modularized version, the present authors added empirical band models for transmittance through the trace gases. Also, continuous functions were made to replace their transmission tables for the principal molecular absorbing species.

6.2 General Features

In this section an effort is made to summarize the basic structure, fundamental calculations and models used in the Lowtran code for estimating atmospheric attenuation by gases and aerosols. Reference is specifically made to the latest fourth version, although at the present time the authors are aware of a recent effort by AFGL on a fifth version. From the authors' evaluation of their recent efforts, it appears that the modularization presented here may be incorporated in their latest version. For instance, the latter is known to have a single separate subroutine for the emission and transmission calculations. The major contribution of the work presented here lies in the separation of that emission and transmission loop into a subroutine for model selection, a subroutine for the equivalent path and individual subroutines for all of the attenuation models in the code.

The Lowtran code is designed for the specific purpose of calculating at low resolutions either atmospheric radiance or transmittance between any two locations in the Earth's atmosphere at frequencies ranging from the ultraviolet (UV) to the infrared (IR). This is accomplished through the use of band models accounting for

resonant gaseous absorption (e.g. H_2O vapor, O_3, HNO_3 vapor and the uniformly-mixed gases), resonant aerosol absorption, non-resonant gaseous absorption (e.g. N_2 and H_2O vapor continua) and scattering by molecules and aerosols. The spectral intervals over which the band models are provided vary from 5 cm^{-1} to 500 cm^{-1}, as shown in Table 1. It should be pointed out that the spectral resolution is generally much lower than the interval over which they are defined. For instance, the models for the principal absorbers are given at 5 cm^{-1} intervals, while their spectral resolution is 20 cm^{-1}. The spectral resolutions for the remaining models is not specified anywhere in the available literature on the code. In this table the spectral definition of the models for aerosol absorption, and for aerosol and molecular scattering are not shown because they are spectrally continuous.

The spectral regions over which the attenuation models are effective are summarized in Table 2. It may be seen in this table that over some regions only a few species attenuate and, therefore, a transmittance of unity may be specified in the calculation of the total transmittance. This table forms the basis for the model selection subroutine introduced in the modularized version for the purpose of simplifying the code structure.

In the discussion that follows, the individual

ATTENUATING SPECIE	MODEL FREQUENCY INTERVAL (cm^{-1})			
	5	50	200	500
H_2O				
UNIFORMLY-MIXED GASES				
O_3				
N_2 CONTINUUM				
H_2O CONTINUUM				
HNO_3				
VISIBLE O_3				
ULTRA VIOLET O_3				

Table 1. Frequency interval of the attenuation band models in the Lowtran code. The models for aerosol absorption and aerosol and molecular scattering are spectrally continuous and, therefore, not shown.

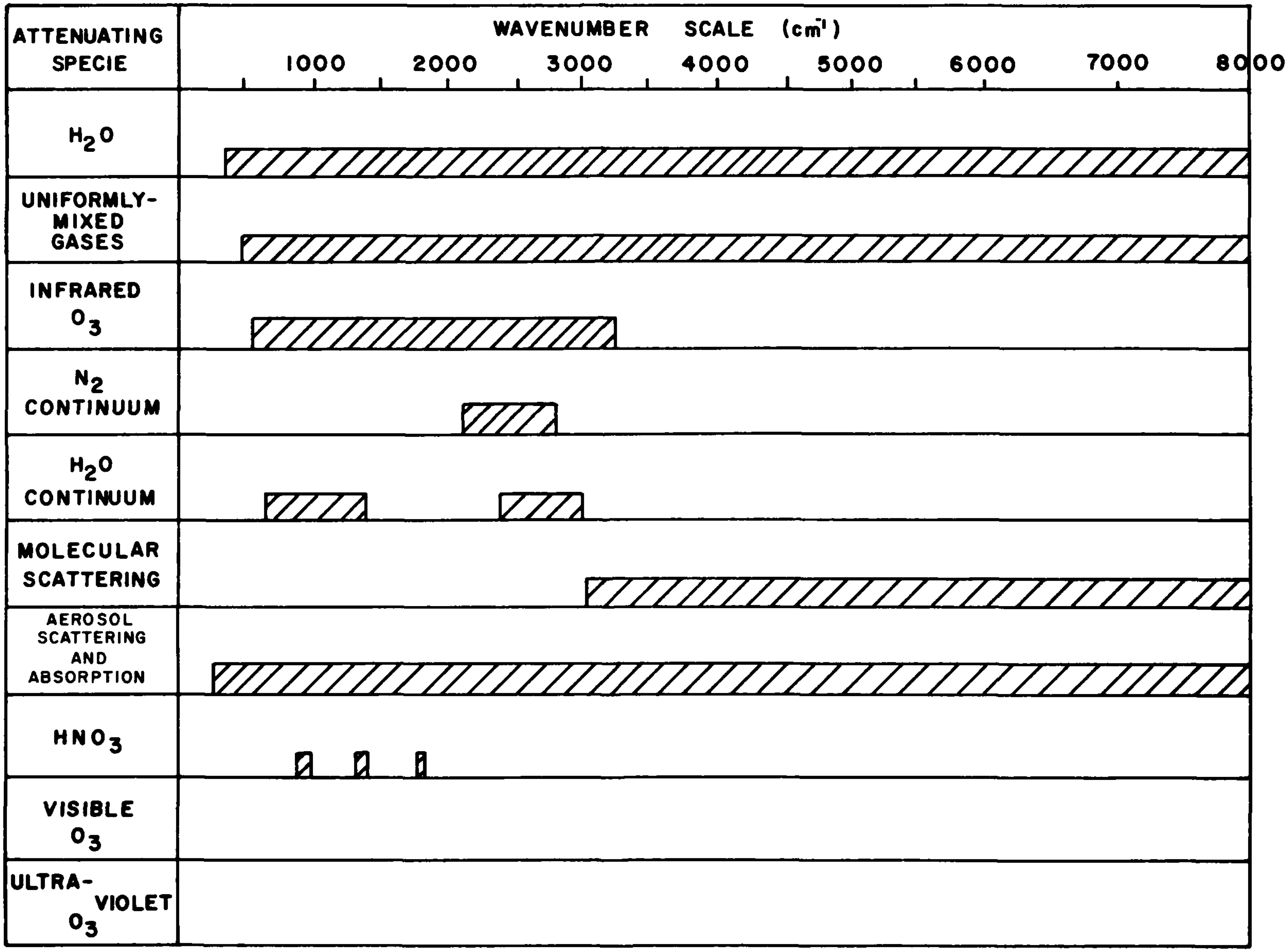

Table 2. Spectral region over which the attenuation models in LOWTRAN are effective.

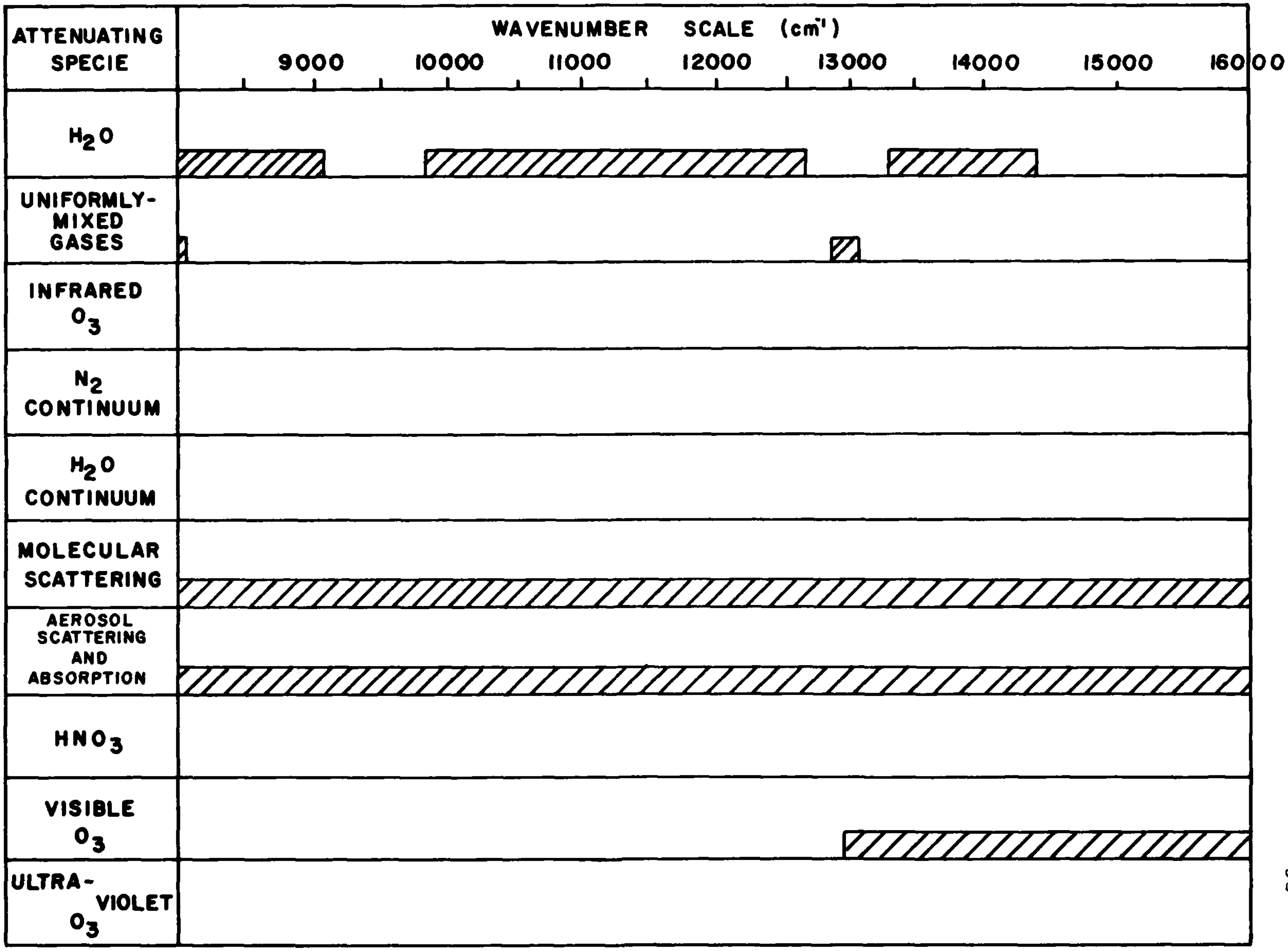

Table 2. (Continued)

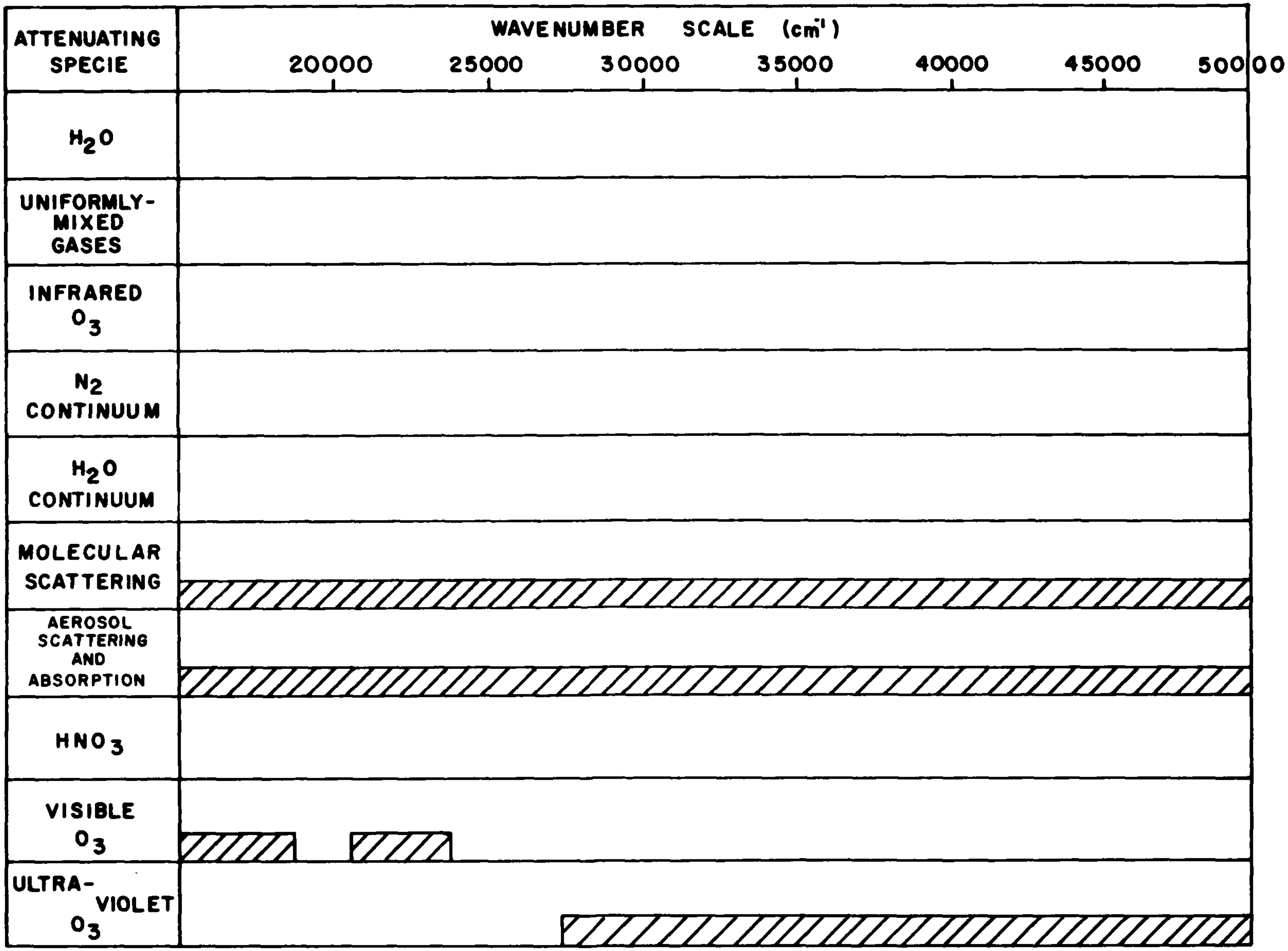

Table 2. (Continued)

attenuation models are grouped together in certain classes and are briefly discussed. Generally speaking, the discussion is restricted to the extent of illustrating the function and parameters which had to be identified in Lowtran for the modularization purpose that followed. An exception is made in the case of the major molecular absorption models (i.e. H_2O vapor, infrared O_3 and the uniformly-mixed gases) because they are replaced with continuous functions in the modularized version. For a comprehensive discussion on the theory of all of the original models the reader is encouraged to study the series of AFGL reports[6-10] on the code, as well as the references therein.

6.3 Resonant Molecular Absorption Models

Molecular resonant absorption is modeled in the code for H_2O vapor, infrared O_3, the uniformly-mixed gases, and HNO_3 vapor. Different approaches are used for the first three listed as compared with the approaches used in connection with O_3 in the visible and ultraviolet regions and with HNO_3 vapor in the infrared.

The models used to account for gaseous absorption by the molecules of H_2O vapor, infrared O_3, and the uniformly-mixed gases are based on Eq.(8), namely

$$\tau = f\{x\}. \tag{8}$$

The developers of Lowtran obtained the parameters n, m, the function f and the spectral constant C' at 5 cm^{-1} intervals using experimental and calculated transmittance data of 20 cm^{-1} resolution. Table 3 shows the values of the parameters, as well as, the equations for the calculation of the absorber amount. The spectral constant C' over the entire spectrum of definition may be found as part of the data input presented in the Appendix. The transmission model for the uniformly-mixed gases was obtained by combining the data for all of these gases in the proportions listed in Table 4. It should be pointed out that the temperature and pressure exponents used in Lowtran for the major absorbers and listed in Table 3 are not the same as the ones developed from the original transmission data. This inconsistency was introduced during the digitizing of the curves for inclusion in the computer code, in order to account more accurately for the temperature dependence[2].

The method used for modeling HNO_3 vapor and the visible and ultraviolet O_3 is similar to the one described above for the major absorbers, except that the function f was specified *a priori* to be an exponential. Thus,

$$\tau = \exp(-CW), \tag{38}$$

where for HNO_3

$$W = \left(\frac{P}{P_o}\right)\left(\frac{T_o}{T}\right) U, \tag{39}$$

$$U = M\, Z \times 10^5, \tag{40}$$

and for O_3

$$W = U = 46.667\ \rho Z. \tag{41}$$

In Eq. (40) M is the mixing ratio profile as tabulated in the Appendix together with the C's, and ρ is the absorber density.

The last of the molecular absorption models is the one for the resonant absorption by atmospheric aerosols. The exponential function in Eq. (38) is assumed

$$\tau = \exp(-CW),$$

where

$$W = U = 3.5336 \times 10^{-6} NZ, \tag{42}$$

and N is the vertical distribution of the number of haze particles. Tabulations are provided of distributions for 5 Km and 23 km visibility, as listed in the Appendix. Other visibilities are treated in the code itself through linear interpolation.

6.4 Non-Resonant Molecular Absorption Models

Non-resonant gaseous molecular absorption is represented by the N_2 and H_2O vapor continuums. The same

modeling approach is used for N_2 as for resonant molecular absorption, that is

$$\tau = \exp(-CW),$$

where

$$W = \left(\frac{P}{P_o}\right)^2 \left(\frac{T_o}{T}\right)^{1.5} U \tag{43}$$

$$U = 0.8\ Z. \tag{44}$$

For the H_2O vapor continuum an exponential function is also used, but with a more elaborate exponent. Thus,

$$\tau = \exp(-\gamma), \tag{45}$$

where

$$\gamma = C_s[P_w + \frac{C_n}{C_s}(P - P_w)]\ U. \tag{46}$$

Here, P_w is the partial pressure of water and C_s and C_n are the self-broadening and nitrogen-broadening spectral constants. The values of these spectral constants depend on the spectral region where the continuum is effective.

In the 8 to 14 μm region

$$C_s = C_o \exp[6.08\ (\frac{296}{T} - 1)], \tag{47}$$

and

$$\frac{C_n}{C_s} = 0.002, \tag{48}$$

while in the 3.5 to 4.2 μm region

$$C_s = C_o \exp[4.56 \left(\frac{296}{T} - 1\right)], \tag{49}$$

and

$$\frac{C_n}{C_s} = 0.120. \tag{50}$$

In these equations the value of C_o is given by

$$C_o = 4.18 + 5578 \exp(-7.87 \times 10^{-3}\nu). \tag{51}$$

ATTENUATING SPECIE	SPECTRAL REGION (cm^{-1})	PRESSURE EXPONENT n	TEMPERATURE EXPONENT m	ABSORBER AMOUNT U
H_2O Vapor	350- 9,195 9,875-12,795 13,400-14,520	0.90	0.45	0.1 ρZ
Uniformly-Mixed Gases	500- 8,070 12,950-13,245	1.75	1.375	Z
Infrared O_3	575- 3,270	0.40	0.20	46.667 ρZ
N_2 Continuum	2,080- 2,740	2.00	1.50	0.8 Z
Aerosol Absorption	333-50,000	0.00	0.00	3.5336×10^{-6} NZ
Aerosol Scattering	333-50,000	0.00	0.00	3.5336×10^{-4} NZ
Molecular Scattering	3,000-50,000	1.00	1.00	9.87×10^{-20} Z
HNO_3 Vapor	850- 920 1,275- 1,350 1,675- 1,735	1.00	1.00	1×10^{5} MZ
Visible and Ultraviolet O_3	13,000-24,000 27,500-50,000	0.00	0.00	46.667 ρZ

Table 3. Absorber parameters in Lowtran for the attenuation models, where ρ is the density, Z the range and M the mixing ratio. The H_2O continuum model is excluded because of its different functional form.

GAS	MOLECULAR WEIGHT	PARTS PER MILLION BY VOLUME (ppm)
CO_2	44	330.0
N_2O	44	0.28
CO	28	0.075
CH_4	16	1.60
O_2	32	2.095×10^5

Table 4. Concentrations of the uniformly-mixed gases used in the combined model.

6.5 Scattering Models

In order to account for atmospheric scattering exponential functions were used again. For scattering by molecules the model is defined as in Eq. (38)

$$\tau = \exp(-CW)$$

where

$$W = \left(\frac{P}{P_o}\right)\left(\frac{T_o}{T}\right) U \tag{52}$$

$$U = 9.87 \times 10^{-20} Z \tag{53}$$

$$C = \nu^4 \tag{54}$$

For aerosol scattering the argument of the assumed exponential function is

$$W = U = 3.5336 \times 10^{-4} NZ \tag{55}$$

VII. Modularization of Lowtran Including the Trace Gases

7.1 Introduction

Considering the generality and broadness in scope of this code it is not surprising that the program structure shows in its present form great complexity. Although the program user is not normally interested in aspects of the code other than the input and output, there are many cases where a basic understanding helps in specific applications. Situations are likely to occur, for instance, where a replacement of one of the several attenuation models is highly desirable. To assist in the implementation of model additions or changes as well as in the extension to other spectral regions and media, the concept of the modularized version was conceived. This version[15] was designed to represent exactly the same calculations as the original, except for the simplification of the program structure into modules or subroutines. However, upon the termination of that task the authors proceeded to add models for the trace gases, as developed during the present scientific effort.

7.2 Structure of Modularized Version

The basic design used was that of a main program which reads input data, computes total transmittance and radiance and generates outputs, and a series of subroutines

which select individual models and compute individual transmittances and absorber amounts. This is shown in Fig. 4. The main operational flow chart follows in Fig. 5. Excluding the four subroutines for the trace gases, the modularized version breaks down the original into one program with 11 subroutines. The flow chart for subroutine ABSORB is shown in Fig. 6. This subroutine computes the equivalent absorber amount for all of the attenuation models according to Eq.(4), which in terms of the meteorological variables becomes

$$W = \int \left(\frac{P(Z)}{P_o}\right)^n \left(\frac{T_o}{T(Z)}\right)^m dU \qquad (56)$$

Figure 7 gives details of the Transmittance/Radiance Loop of program Main. It is worth noting that the modularized version of Lowtran being done by AFGL separates this loop into a subprogram. The modularization discussed in this text leaves the loop as part of the main program, but extracts individual subroutines for the calculation of the equivalent absorber amount, the frequency selection, and the attenuation models.

The flow chart for FREQSL subroutine is shown in Fig. 8. This subroutine is designed to simplify the process of arriving at the individual models effective at the frequency of interest. It should also assist the

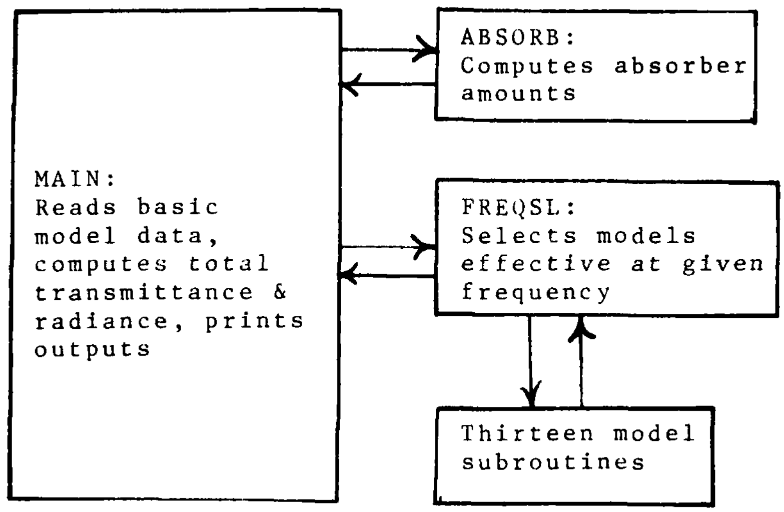

Fig. 4. Conceptual flow chart of modularized Lowtran.

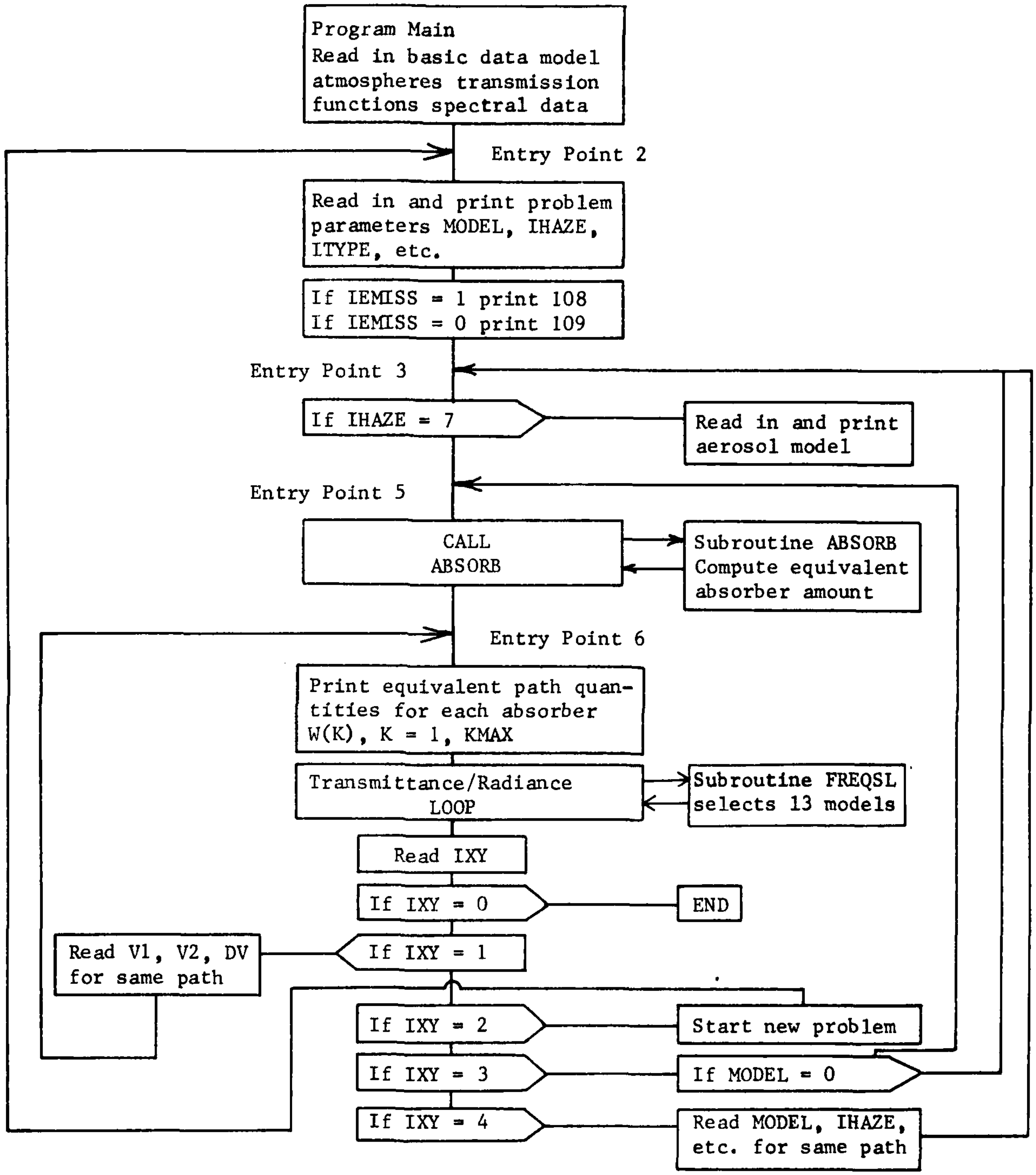

Fig. 5. General flow chart for Modularized Lowtran 4

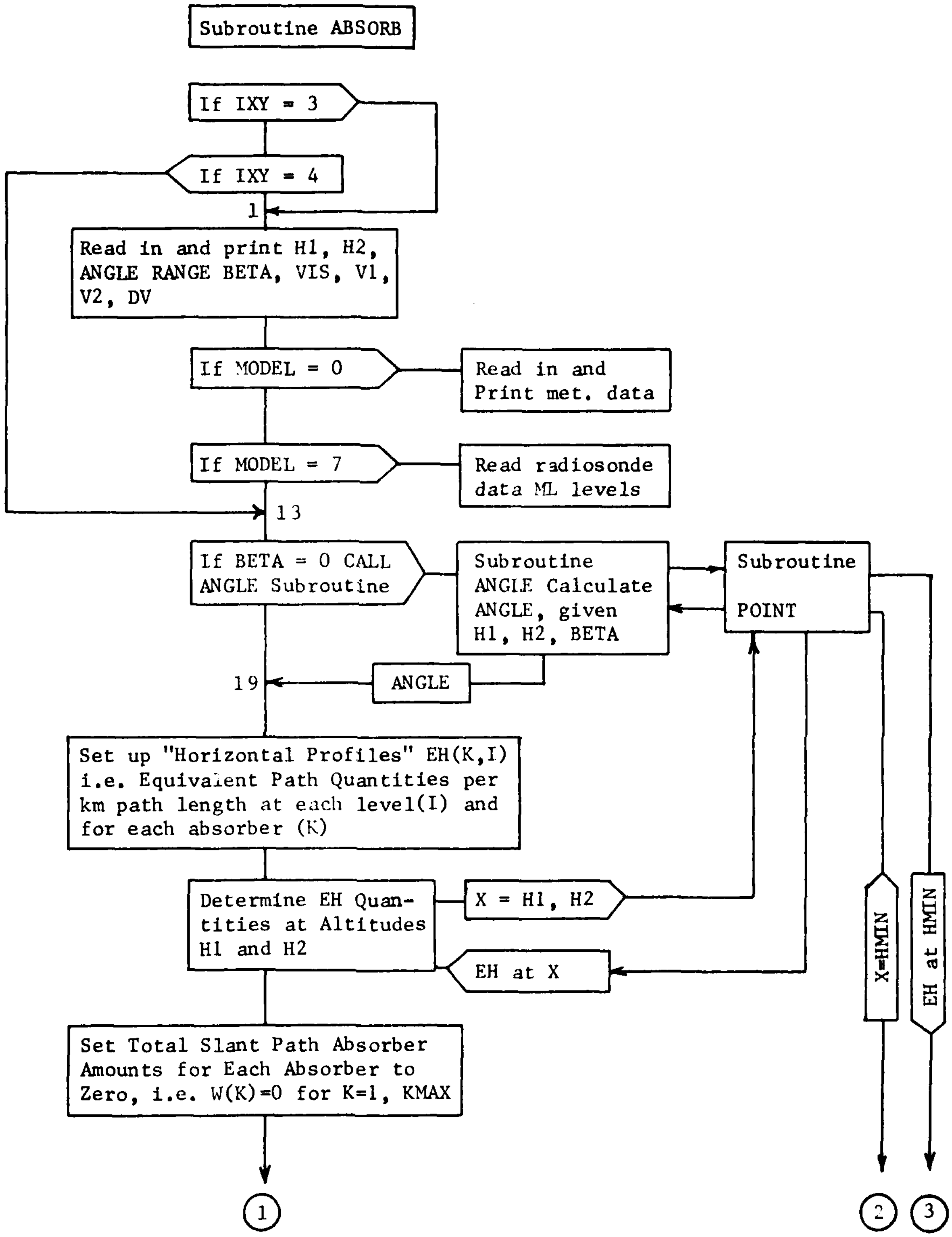

Fig. 6. Flow chart for subroutine ABSORB, computing equivalent path quantities

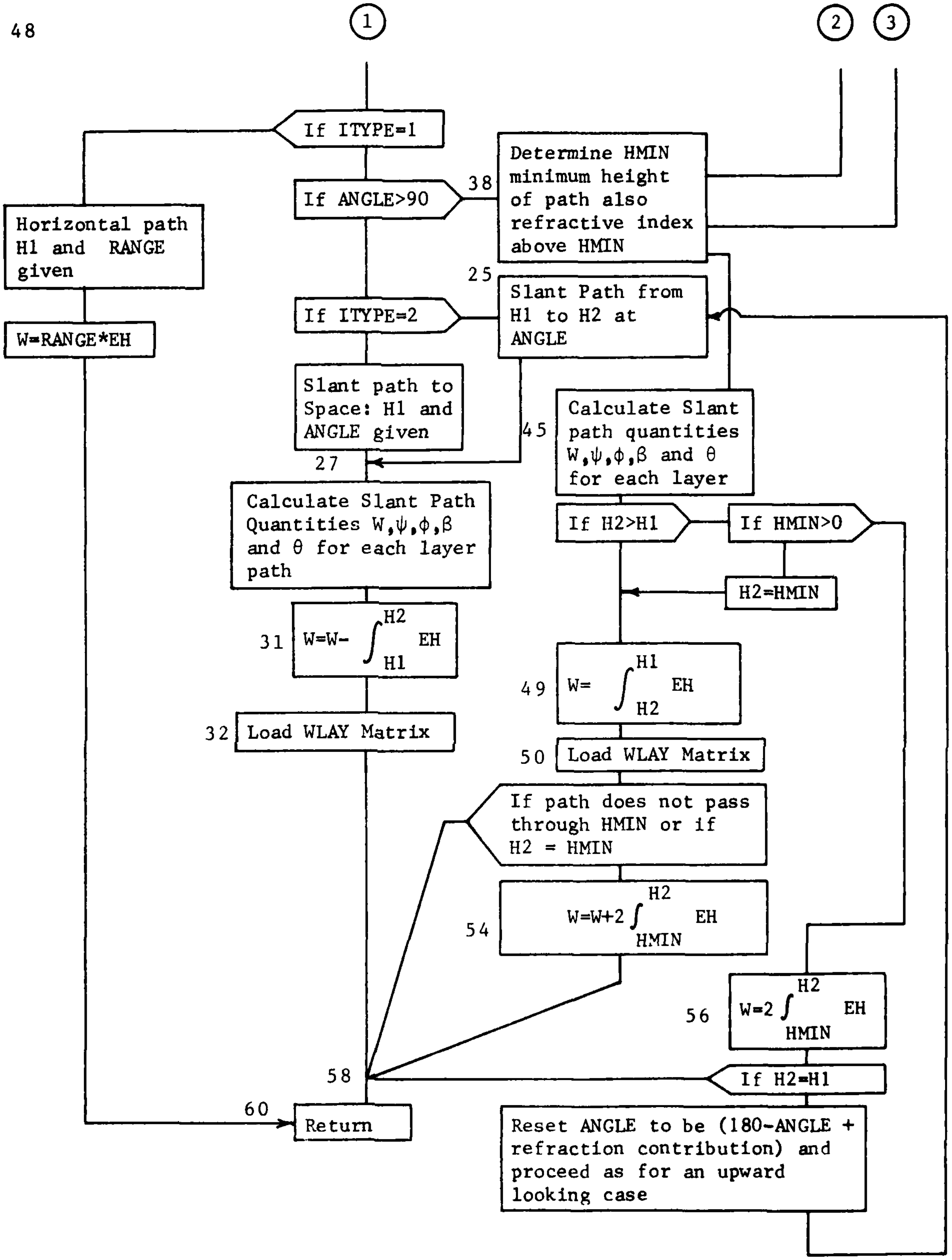
1
2
3
If ITYPE=1
If ANGLE>90
38
Determine HMIN minimum height of path also refractive index above HMIN
Horizontal path H1 and RANGE given
W=RANGE*EH
25
Slant Path from H1 to H2 at ANGLE
If ITYPE=2
Slant path to Space: H1 and ANGLE given
45
Calculate Slant path quantities W,ψ,φ,β and θ for each layer
27
Calculate Slant Path Quantities W,ψ,φ,β and θ for each layer path
If H2>H1
If HMIN>0
H2=HMIN
31
W=W- ∫ H1 H2 EH
49
W= ∫ H2 H1 EH
32
Load WLAY Matrix
50
Load WLAY Matrix
If path does not pass through HMIN or if H2 = HMIN
54
W=W+2 ∫ HMIN H2 EH
56
W=2 ∫ HMIN H2 EH
58
If H2=H1
60
Return
Reset ANGLE to be (180-ANGLE + refraction contribution) and proceed as for an upward looking case

Fig. 6. (cont'd)

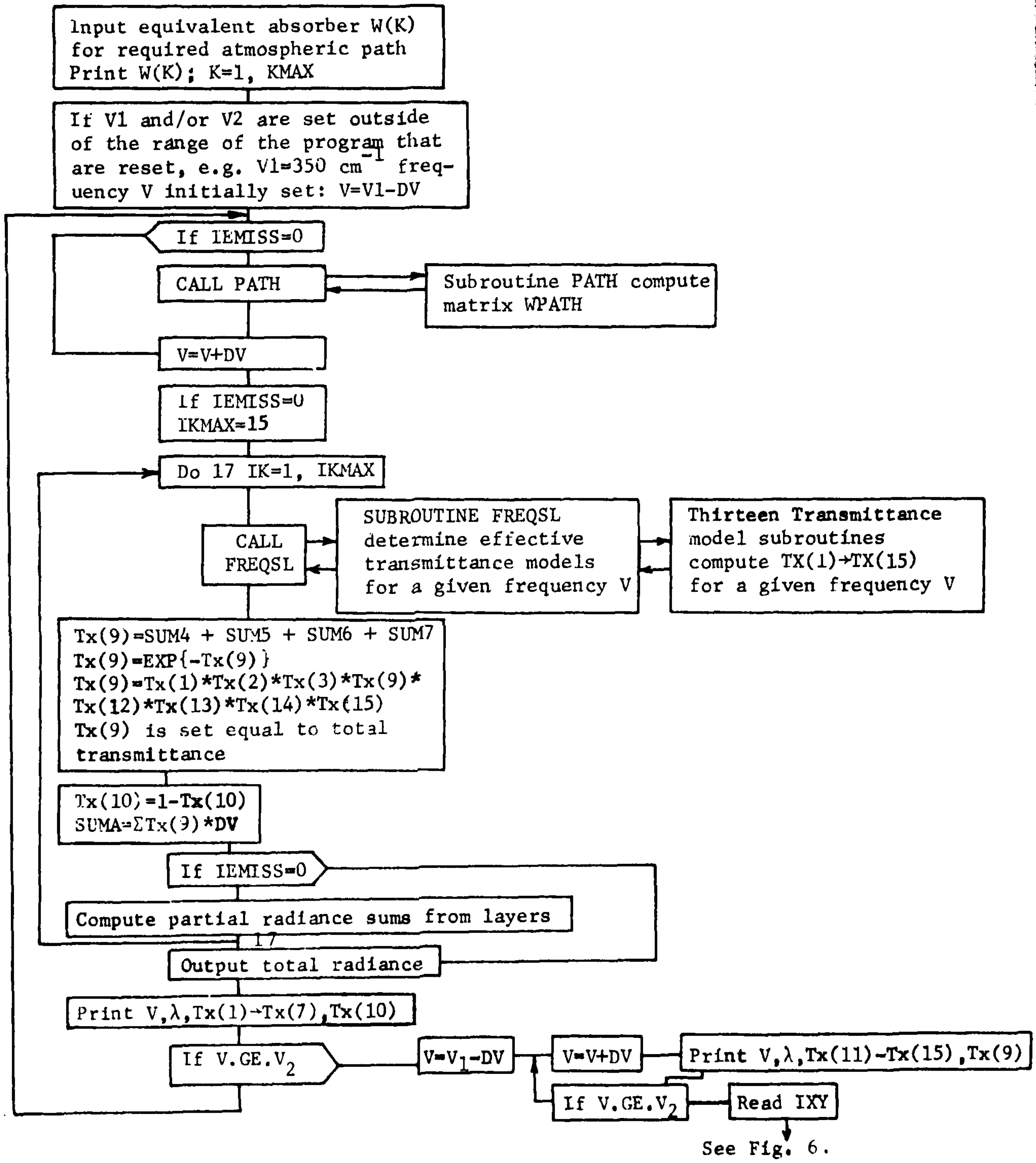

Fig. 7. Flow chart for transmittance/radiance loop.

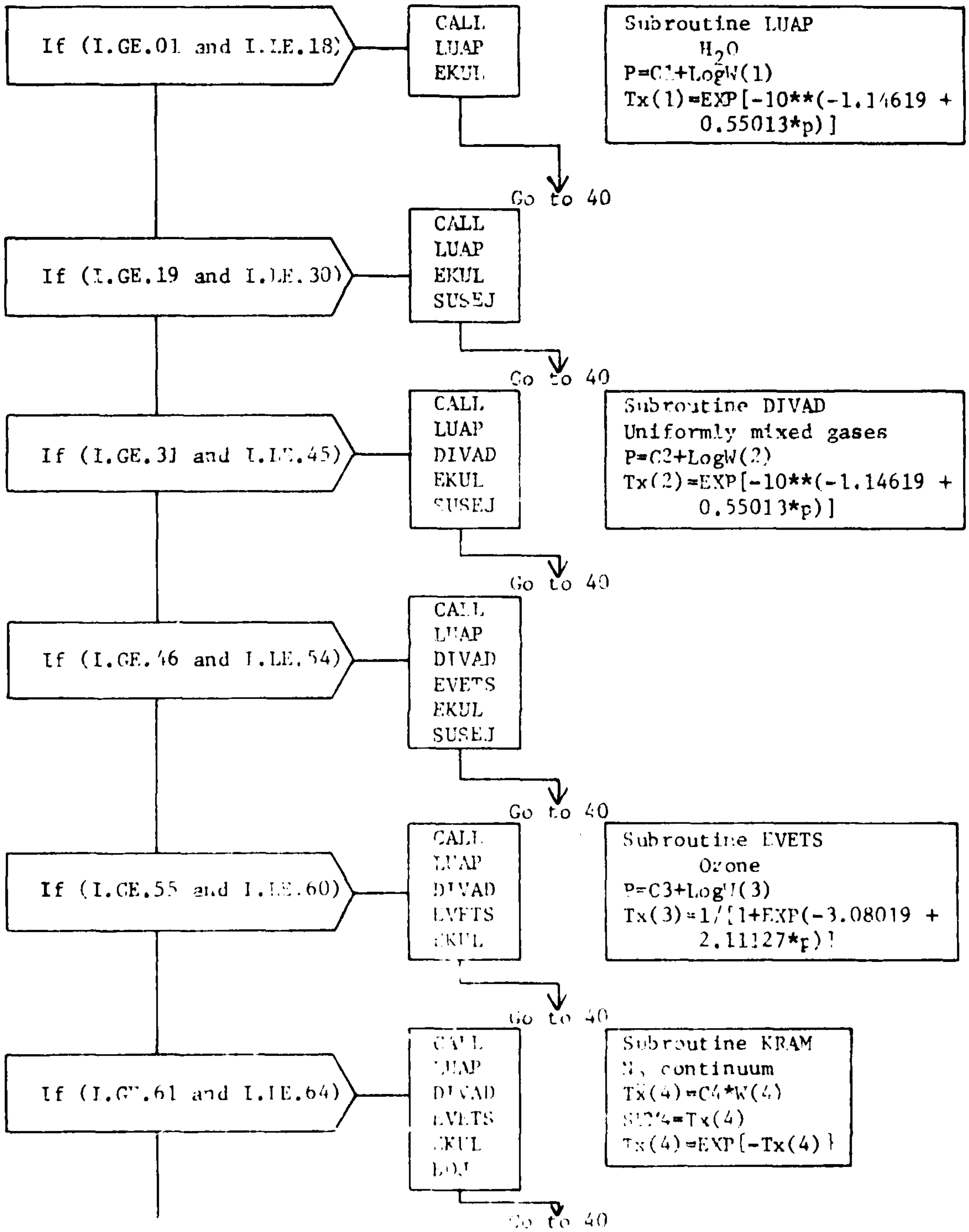

Fig. 8. Flow chart for subroutine TREQSL and thirteen transmittance model subroutines.

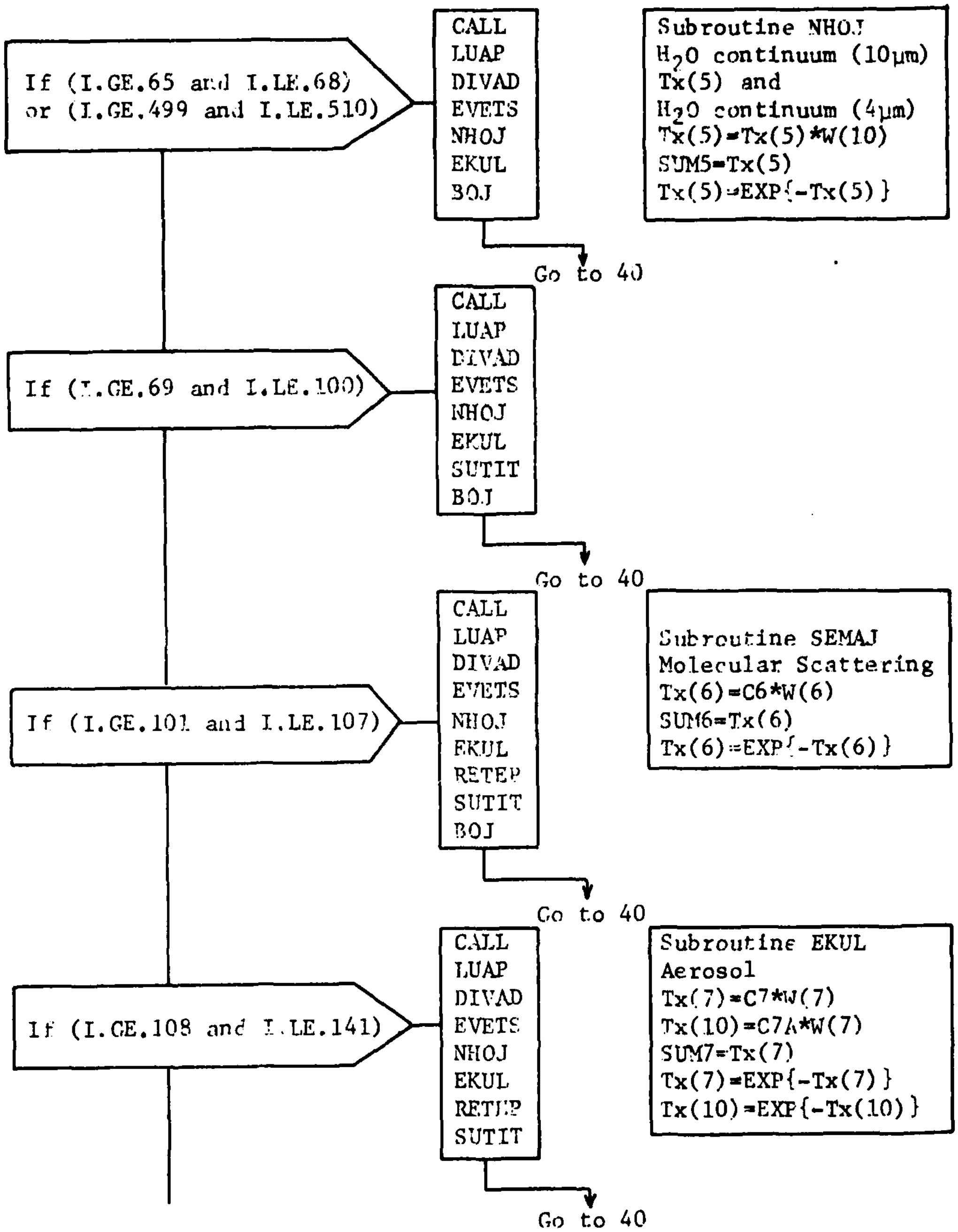

Fig. 8. Continued

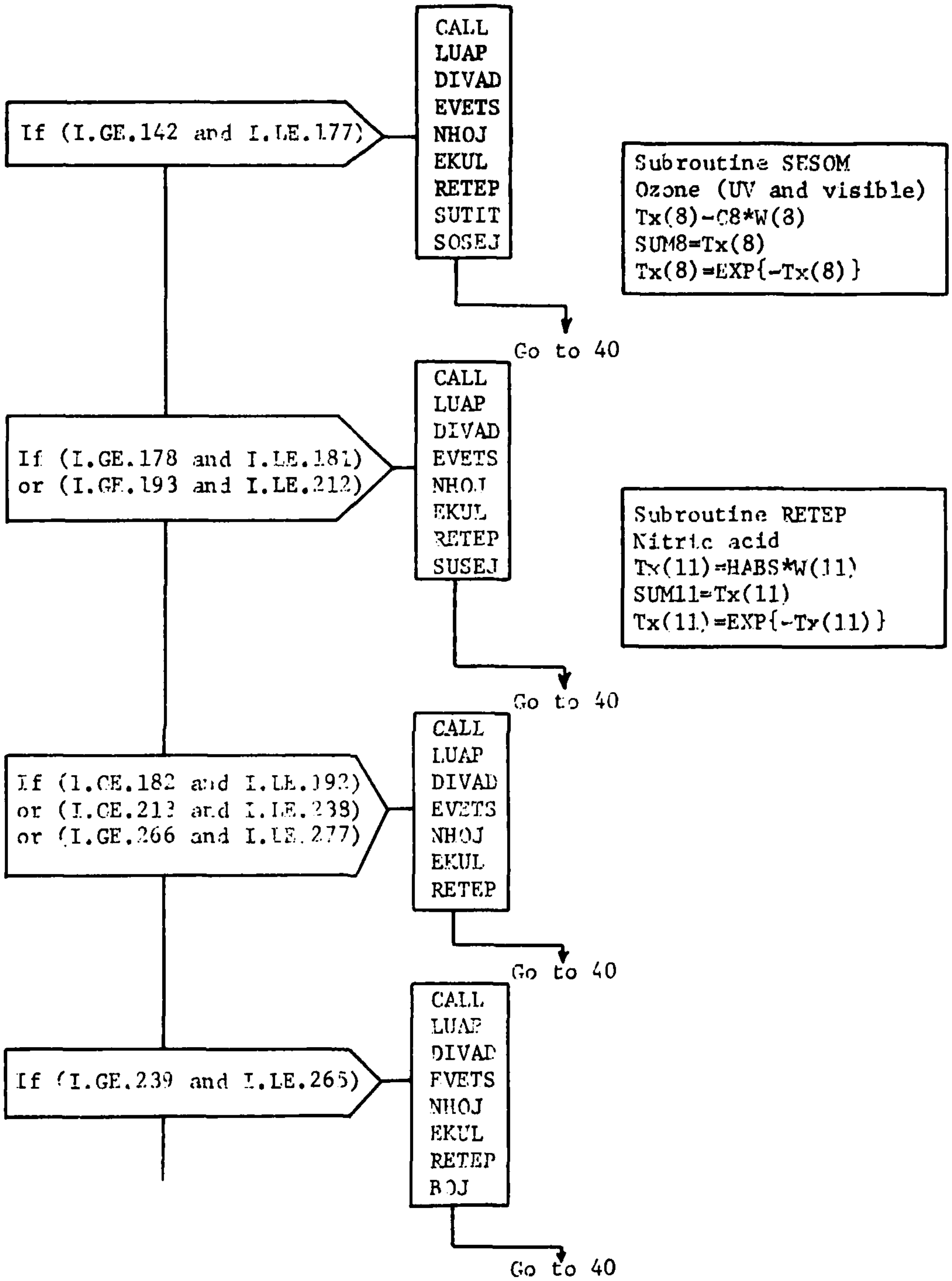

Fig. 8. Continued

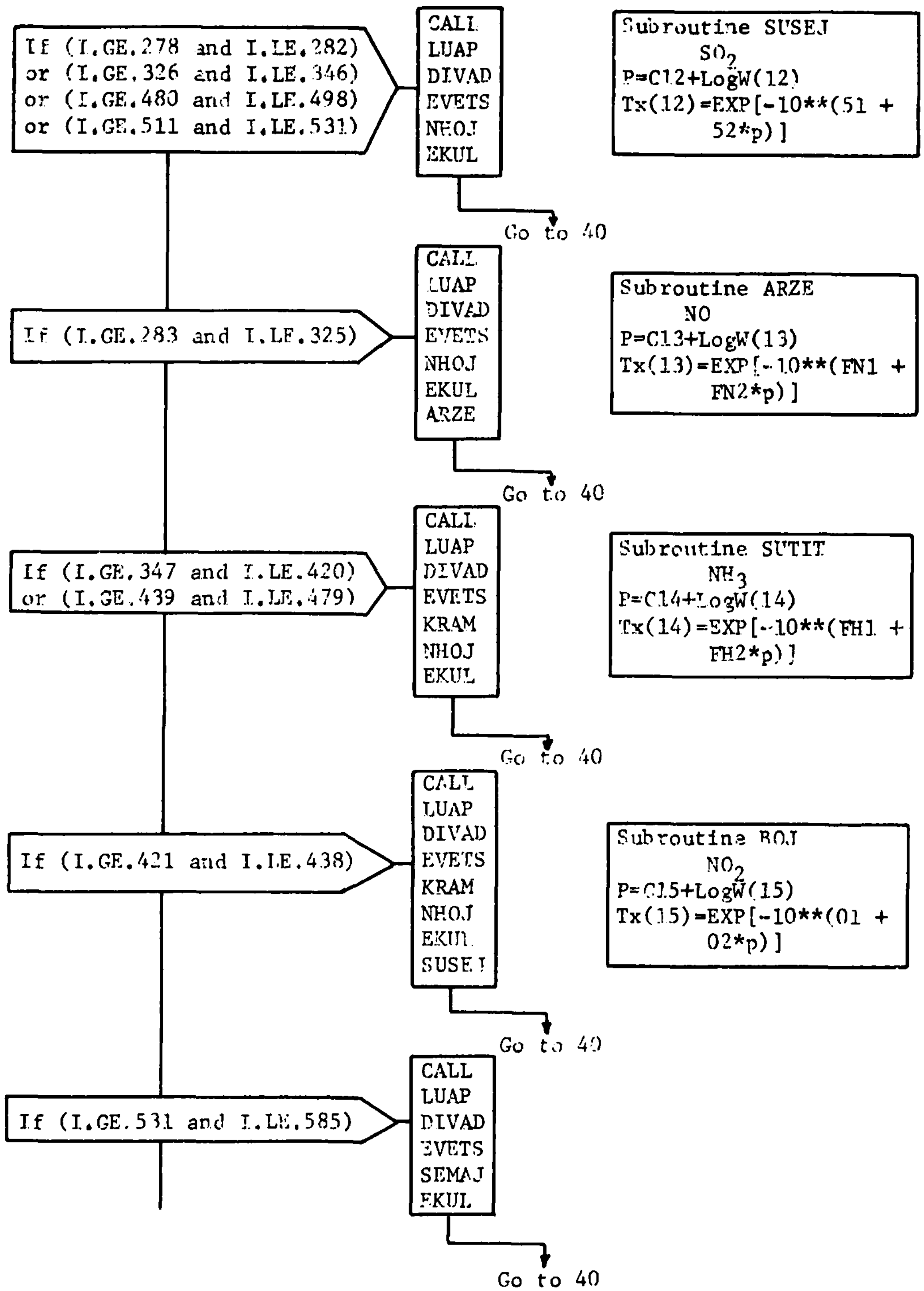

Fig. 8. Continued

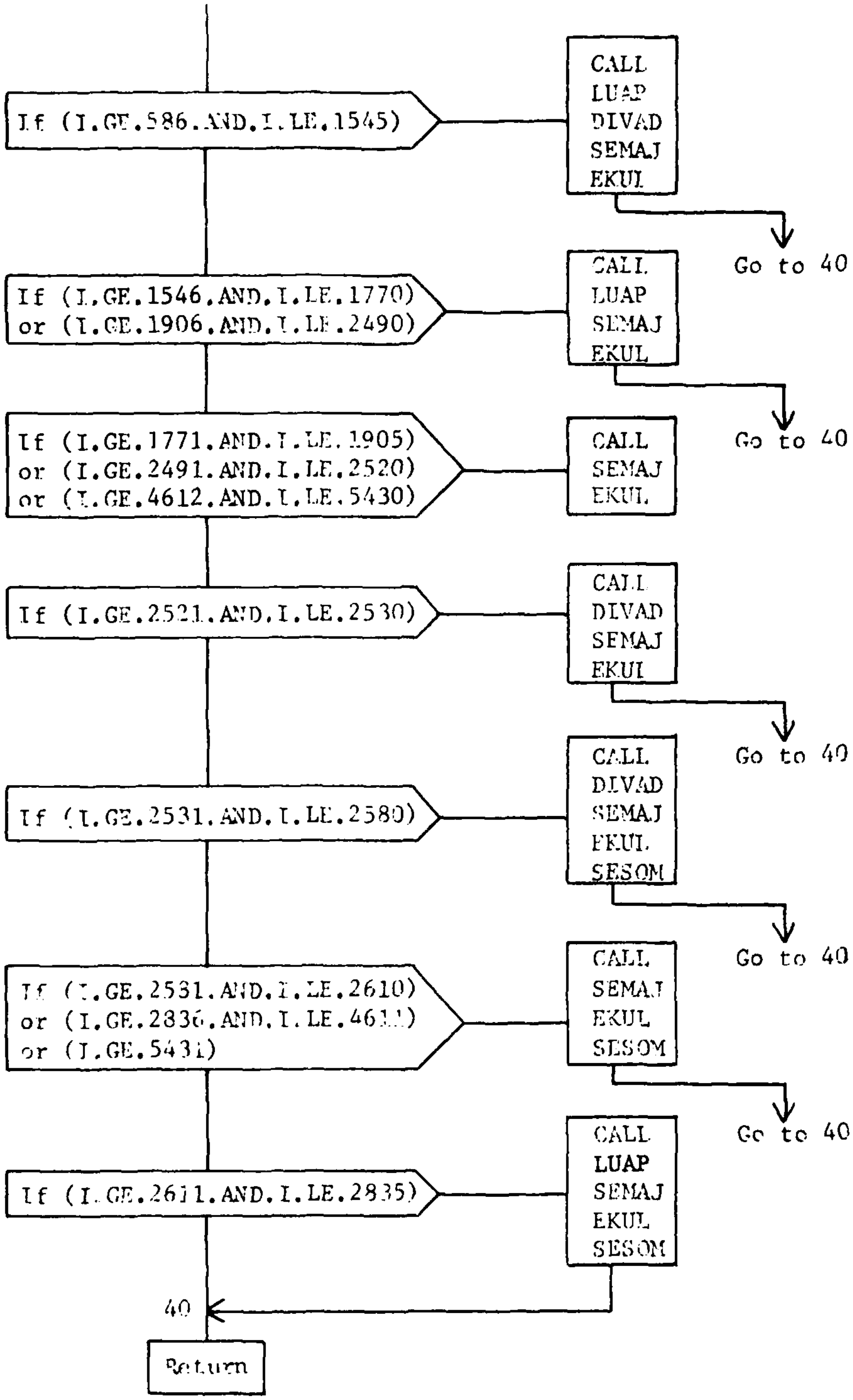

Fig. 8. Continued

user who desires to replace or add models to the program and it should reduce the overall computational time. This subroutine is based on Tables 2 and 8.

7.3 Models for H_2O Vapor, Infrared O_3 and the Uniformly-Mixed Gases

As indicated above, all the attenuation models were extracted from the main program and placed into subroutines. The models were left basically in the same structural form except for the models for HNO_3 and H_2O vapor, infrared O_3 and the uniformly-mixed gases. The change in the first was to arrange it along the same form as in the other models originally available in Lowtran. That is, the spectral parameters were extracted from the subroutine and read at the beginning of program MAIN. The changes in the latter three gases (i.e. H_2O vapor, O_3 in the infrared and the uniformly-mixed gases) were based on a previous work by Pierluissi et al.[2] on the representation of the tabulated transmission functions by analytical functions. The other principal change consisted of adding models for the trace gases SO_2, NO, NO_2 and NH_3.

To arrive at the analytical function for modeling H_2O vapor and the uniformly-mixed gases the double exponential expression

$$\tau = \exp(-10^{a_o + a_1 x}) \qquad (57)$$

where x is as in Eq.) and a_o and a_1 are absorber

constants, was curve-fitted to the 134 values of τ and x tabulated in Lowtran. The values found are $a_o = -1.14619$ and $a_1 = 0.55013$, and it reproduced the tabulated transmittance with a standard deviation of 0.005. For O_3 the function adopted is given by

$$\tau = \frac{1}{1 + e^{a_o + a_1 x}} \tag{58}$$

where $a_o = -3.08019$, $a_1 = 2.11127$, and the tabulated data is reproduced with a standard deviation of 0.007. Note in each one of these functions that the 134 tabulated values are replaced with two and, hence, their adoption reduces the computer storage requirements. Also, they inherently offer exponential interpolation while with the present tabulation linear interpolation is being used. Finally, there is no need for the small optical thickness (i.e. $0.999 \leq \tau \leq 1$) correction inserted in Lowtran 4, as required by its radiance calculational scheme.

7.4 Models for Trace Gases SO_2, NO, NO_2, and NH_3

Absorption by the trace gases was incorporated in Lowtran using a somewhat similar procedure. Empirical transmission functions were first obtained from a computerized procedure which replaced the classical manual graphical techniques. The procedure is explained in Chapter III of this report and has been proposed to the scientific community[11].

Instead of either representing the transmission function by a table or by a single function, it was divided into nine segments for each absorber. The individual curve segments are summarized in Table 5, each one being represented by the function

$$\tau = \exp(-10^{a_0 + a_1 x}) \tag{59}$$

For each absorber x is computed with Eqs. (8) through (11) and the relation

$$U = 0.772 \times 10^{-4} \text{ ppm } \rho_a Z \tag{60}$$

where ppm is the parts per million by volume, ρ_a is the air density in gm/m^3 and Z is the range in kilometers. Table 6 lists the ppm and temperature and pressure exponents used in the modularized code for the individual trace gases. The ppm values are read as input through a separate card which may be easily changed according to the needs of the user. The constants C' are tabulated in Table 7. The spectral coverage for each gas is depicted in Table 8. The models are for a resolution of 20 cm^{-1} and are defined at 5 cm^{-1} through their spectral regions of effectiveness. Their mean standard deviation in fitting the original line-by-line data is about 0.008. Figure 9 depicts the transmission functions for the four trace gases considered.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x-INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq -1.057$	0.0682	0.9894
2	0.900 ~ 0.800	-1.057 ~ -0.725	0.0594	0.9811
3	0.800 ~ 0.700	-0.725 ~ -0.514	0.0492	0.9670
4	0.700 ~ 0.600	-0.514 ~ -0.350	0.0408	0.9506
5	0.600 ~ 0.500	-0.350 ~ -0.208	0.0343	0.9319
6	0.500 ~ 0.400	-0.208 ~ -0.074	0.0295	0.9091
7	0.400 ~ 0.300	-0.074 ~ 0.061	0.0273	0.8792
8	0.300 ~ 0.200	0.061 ~ 0.212	0.0300	0.8353
9	0.200 ~ 0.0	$x \geq 0.212$	0.0466	0.7568

Table 5a. Constants for the curve segments in the empirical transmission function for SO_2.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x- INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq -1.158$	-0.0228	0.8240
2	0.900 ~ 0.800	-1.158 ~ -0.684	-0.1822	0.6864
3	0.800 ~ 0.700	-0.684 ~ -0.333	-0.2537	0.5818
4	0.700 ~ 0.600	-0.333 ~ -0.047	-0.2660	0.5450
5	0.600 ~ 0.500	-0.047 ~ 0.199	-0.2663	0.5388
6	0.500 ~ 0.400	0.199 ~ 0.419	-0.2685	0.5497
7	0.400 ~ 0.300	0.419 ~ 0.626	-0.2785	0.5737
8	0.300 ~ 0.200	0.626 ~ 0.833	-0.3000	0.6080
9	0.200 ~ 0.0	$x \geq 0.833$	-0.3373	0.6528

Table 5b. Constants for the curve segments in the empirical transmission function for NO.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x-INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq 0.215$	-1.1877	0.9771
2	0.900 ~ 0.800	0.215 ~ 0.556	-1.1835	0.9577
3	0.800 ~ 0.700	0.556 ~ 0.775	-1.1668	0.9277
4	0.700 ~ 0.600	0.775 ~ 0.949	-1.1416	0.8952
5	0.600 ~ 0.500	0.949 ~ 1.104	-1.1063	0.8580
6	0.500 ~ 0.400	1.104 ~ 1.252	-1.0615	0.8174
7	0.400 ~ 0.300	1.252 ~ 1.406	-1.0055	0.7727
8	0.300 ~ 0.200	1.406 ~ 1.579	-0.9400	0.7260
9	0.200 ~ 0.0	$x \geq 1.579$	-0.8683	0.6807

Table 5c. Constants for the curve segments in the empirical transmission function for NO_2.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x - INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq -1.444$	0.2775	0.8692
2	0.900 ~ 0.800	-1.444 ~ -1.005	0.0962	0.7436
3	0.800 ~ 0.700	-1.005 ~ -0.661	-0.0570	0.5913
4	0.700 ~ 0.600	-0.661 ~ -0.340	-0.1261	0.4867
5	0.600 ~ 0.500	-0.340 ~ -0.033	-0.1450	0.4312
6	0.500 ~ 0.400	-0.033 ~ 0.267	-0.1459	0.4037
7	0.400 ~ 0.300	0.267 ~ 0.575	-0.1409	0.3852
8	0.300 ~ 0.200	0.575 ~ 0.921	-0.1290	0.3645
9	0.200 ~ 0.0	$x \geq 0.921$	-0.1224	0.3573

Table 5d. Constants for the curve segments in the empirical transmission function for NH_3.

TRACE GAS	SPECTRAL REGION (cm^{-1})	PRESSURE EXPONENT n	TEMPERATURE EXPONENT m	PARTS PER MILLION BY VOLUME ppm
SO_2	440- 615 1,055-1,250 1,310-1,410	0.07122	0.06159	0.221
NO	1,760-1,970	0.90098	1.01192	0.250
NO_2	655- 880 1,540-1,670 2,840-2,895	0.18066	0.20911	0.090
NH_3	670-1,230	0.52125	-0.60438	0.200

Table 6. Absorber parameters in Modularized Lowtran used with the models for the trace gases.

WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'
440	-2.987	1070	-1.653	1320	-1.237
445	-2.330	1075	-1.443	1325	-0.494
450	-1.791	1080	-1.252	1330	0.139
455	-1.370	1085	-1.080	1335	0.613
460	-1.041	1090	-0.926	1340	0.899
465	-0.795	1095	-0.787	1345	1.043
470	-0.613	1100	-0.661	1350	1.090
475	-0.469	1105	-0.544	1355	1.097
480	-0.346	1110	-0.434	1360	1.104
485	-0.233	1115	-0.329	1365	1.093
490	-0.126	1120	-0.230	1370	1.118
495	-0.037	1125	-0.139	1375	1.088
500	0.0	1130	-0.073	1380	0.926
505	-0.008	1135	-0.047	1385	0.534
510	-0.052	1140	-0.057	1390	-0.067
515	-0.102	1145	-0.083	1395	-0.804
520	-0.102	1150	-0.098	1400	-0.768
525	-0.044	1155	-0.071	1405	-1.687
530	0.013	1160	-0.020	1410	-2.469
535	0.039	1165	0.014	2450	-3.669
540	0.014	1170	0.011	2455	-2.855
545	-0.056	1175	-0.040	2460	-2.131
550	-0.141	1180	-0.123	2465	-1.528

Table 7a. The spectral coefficient $C'(\nu)$ for SO_2.

WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'
555	-0.221	1185	-0.213	2470	-1.076
560	-0.294	1190	-0.301	2475	-0.805
565	-0.366	1195	-0.388	2480	-0.647
570	-0.442	1200	-0.481	2485	-0.571
575	-0.529	1205	-0.586	2490	-0.549
580	-0.635	1210	-0.707	2495	-0.539
585	-0.766	1215	-0.843	2500	-0.536
590	-0.934	1220	-0.996	2505	-0.517
595	-1.157	1225	-1.165	2510	-0.528
600	-1.457	1230	-1.351	2515	-0.691
605	-1.862	1235	-1.554	2520	-1.073
610	-2.420	1240	-1.777	2525	-1.673
615	-3.094	1245	-2.033	2530	-2.414
1055	-2.604	1250	-2.369	2535	-2.207
1060	-2.156	1310	-3.010		
1065	-1.884	1315	-2.080		

Table 7a. (Continued)

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
1760	-2.691	1835	-0.231	1910	0.003
1765	-2.521	1840	-0.176	1915	-0.032
1770	-2.328	1845	-0.144	1920	-0.105
1775	-2.115	1850	-0.143	1925	-0.211
1780	-1.894	1855	-0.188	1930	-0.352
1785	-1.685	1860	-0.244	1935	-0.529
1790	-1.485	1865	-0.342	1940	-0.742
1795	-1.296	1870	-0.434	1945	-0.992
1800	-1.117	1875	-0.471	1950	-1.282
1805	-0.947	1880	-0.483	1955	-1.610
1810	-0.792	1885	-0.392	1960	-1.975
1815	-0.649	1890	-0.266	1965	-2.374
1820	-0.519	1895	-0.151	1970	-2.806
1825	-0.407	1900	-0.046		
1830	-0.311	1905	-0.001		

Table 7b. The spectral coefficient $C'(\nu)$ for NO.

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
655	-0.844	800	-0.255	1,600	2.616
660	-0.760	805	-0.286	1,605	2.616
665	-0.676	810	-0.315	1,610	2.606
670	-0.608	815	-0.334	1,615	2.608
675	-0.543	820	-0.352	1,620	2.643
680	-0.496	825	-0.366	1,625	2.682
685	-0.450	830	-0.396	1,630	2.672
690	-0.414	835	-0.423	1,635	2.576
695	-0.383	840	-0.459	1,640	2.350
700	-0.326	845	-0.498	1,645	1.955
705	-0.289	850	-0.541	1,650	1.346
710	-0.217	855	-0.586	1,655	0.596
715	-0.140	860	-0.630	1,660	-0.258
720	-0.097	865	-0.676	1,665	-1.214
725	-0.034	870	-0.720	1,670	-1.951
730	-0.031	875	-0.766	2,840	-1.220
735	-0.082	880	-0.809	2,845	-0.644
740	-0.139	1,540	-2.428	2,850	-0.253
745	-0.216	1,545	-1.494	2,855	0.052
750	-0.249	1,550	-0.647	2,860	0.326
755	-0.207	1,555	0.122	2,865	0.574
760	-0.117	1,560	0.756	2,870	0.792

Table 7c. The spectral coefficient $C'(\nu)$ for NO_2.

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
765	-0.047	1,565	1.230	2,875	0.978
770	0.000	1,570	1.568	2,880	1.122
775	0.009	1,575	1.855	2,885	1.216
780	-0.046	1,580	2.104	2,890	1.252
785	-0.100	1,585	2.310	2,895	1.249
790	-0.148	1,590	2.469		
795	-0.214	1,595	2.573		

Table 7c. (Continued)

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
690	-2.603	875	-1.124	1,060	-0.589
695	-2.456	880	-1.155	1,065	-0.565
700	-2.290	885	-1.161	1,070	-0.537
705	-2.128	890	-1.143	1,075	-0.510
710	-1.980	895	-1.139	1,080	-0.512
715	-2.225	900	-1.117	1,085	-0.528
720	-1.823	905	-1.107	1,090	-0.575
725	-1.744	910	-0.844	1,095	-0.625
730	-1.674	915	-0.558	1,100	-0.668
735	-1.577	920	-0.238	1,105	-0.694
740	-1.481	925	-0.042	1,110	-0.717
745	-1.372	930	-0.002	1,115	-0.740
750	-1.284	935	-0.157	1,120	-0.774
755	-1.207	940	-0.436	1,125	-0.834
760	-1.128	945	-0.610	1,130	-0.905
765	-1.061	950	-0.548	1,135	-0.977
770	-1.004	955	-0.352	1,140	-1.042
775	-0.947	960	-0.139	1,145	-1.133
780	-0.886	965	-0.095	1,150	-1.219
785	-0.876	970	-0.365	1,155	-1.301
790	-0.872	975	-0.729	1,160	-1.383
795	-0.869	980	-1.048	1,165	-1.488
800	-0.872	985	-1.275	1,170	-1.594

Table 7d. The spectral coefficient $C'(\nu)$ for NH_3.

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
805	-0.848	990	-1.257	1,175	-1.696
810	-0.811	995	-1.142	1,180	-1.796
815	-0.772	1,000	-1.053	1,185	-1.873
820	-0.773	1,005	-0.963	1,190	-1.936
825	-0.793	1,010	-0.920	1,195	-1.991
830	-0.825	1,015	-0.944	1,200	-2.080
835	-0.869	1,020	-0.889	1,205	-2.183
840	-0.894	1,025	-0.829	1,210	-2.292
845	-0.890	1,030	-0.736	1,215	-2.404
850	-0.873	1,035	-0.644	1,220	-2.529
855	-0.868	1,040	-0.596	1,225	-2.639
860	-0.907	1,045	-0.569	1,230	-2.732
865	-0.965	1,050	-0.572		
870	-1.045	1,055	-0.590		

Table 7d. (Continued)

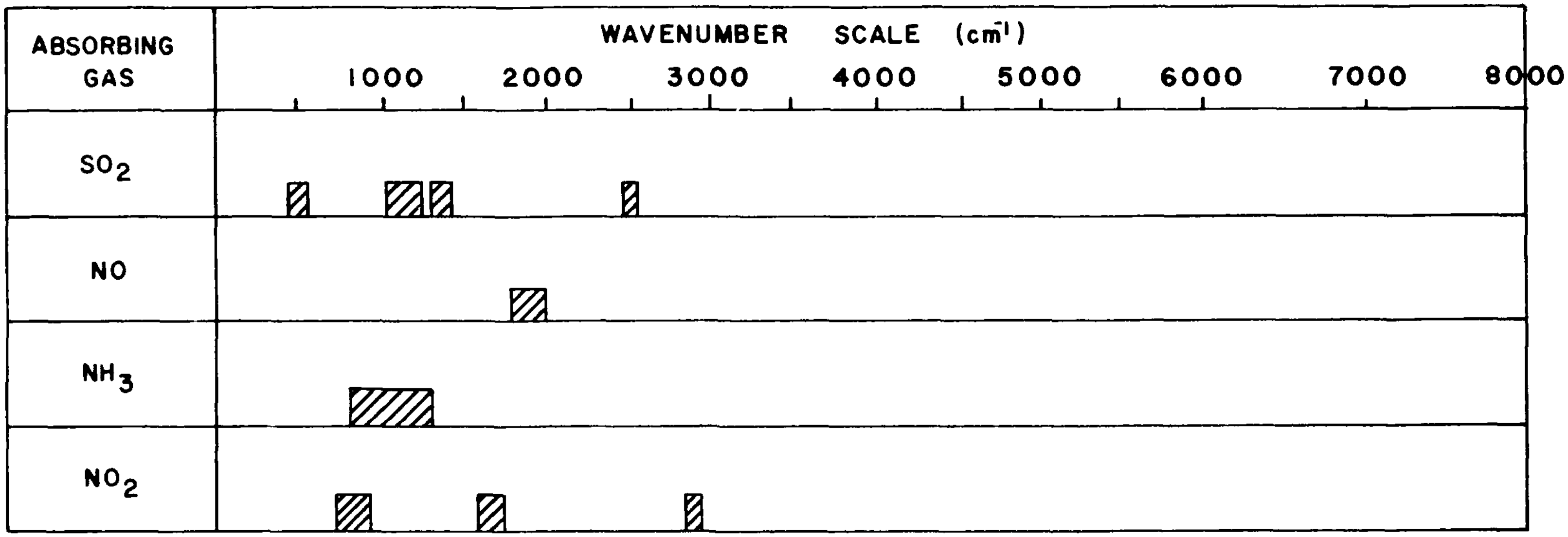

Table 8. Absorption frequency region of the trace gases in the atmosphere.

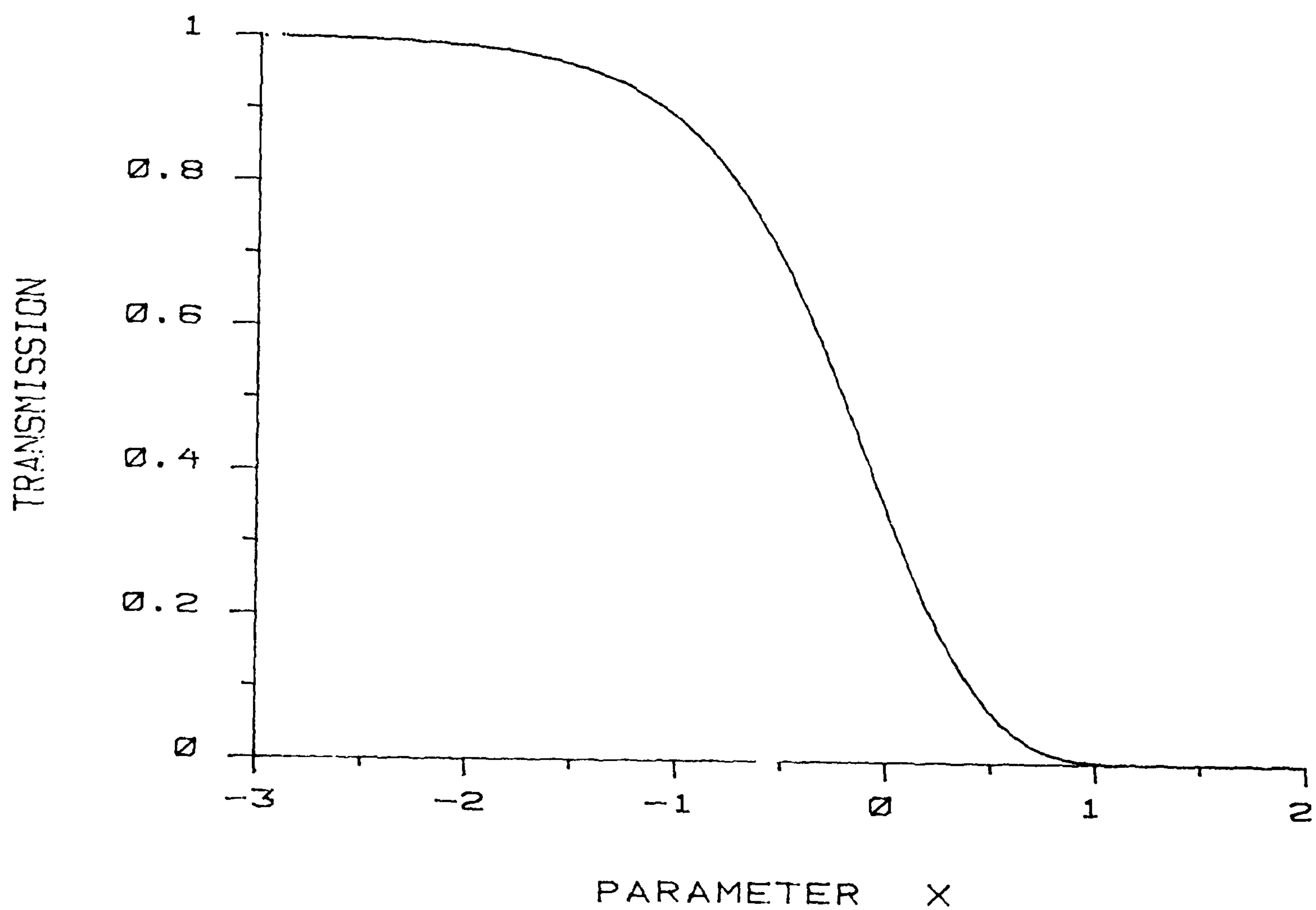

Fig. 9a. Empirical transmission function for SO_2.

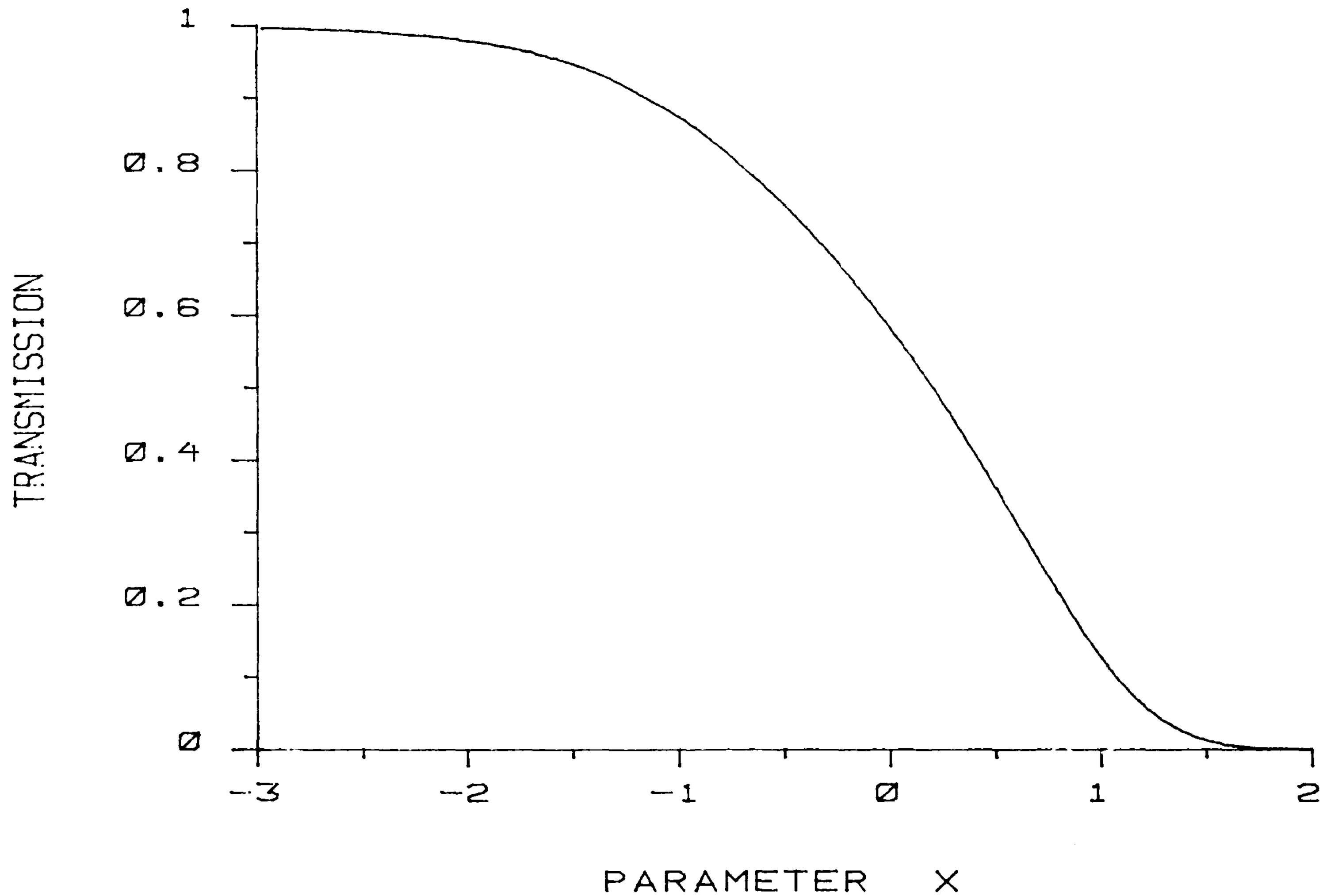

Fig. 9b. Empirical transmission function for NO.

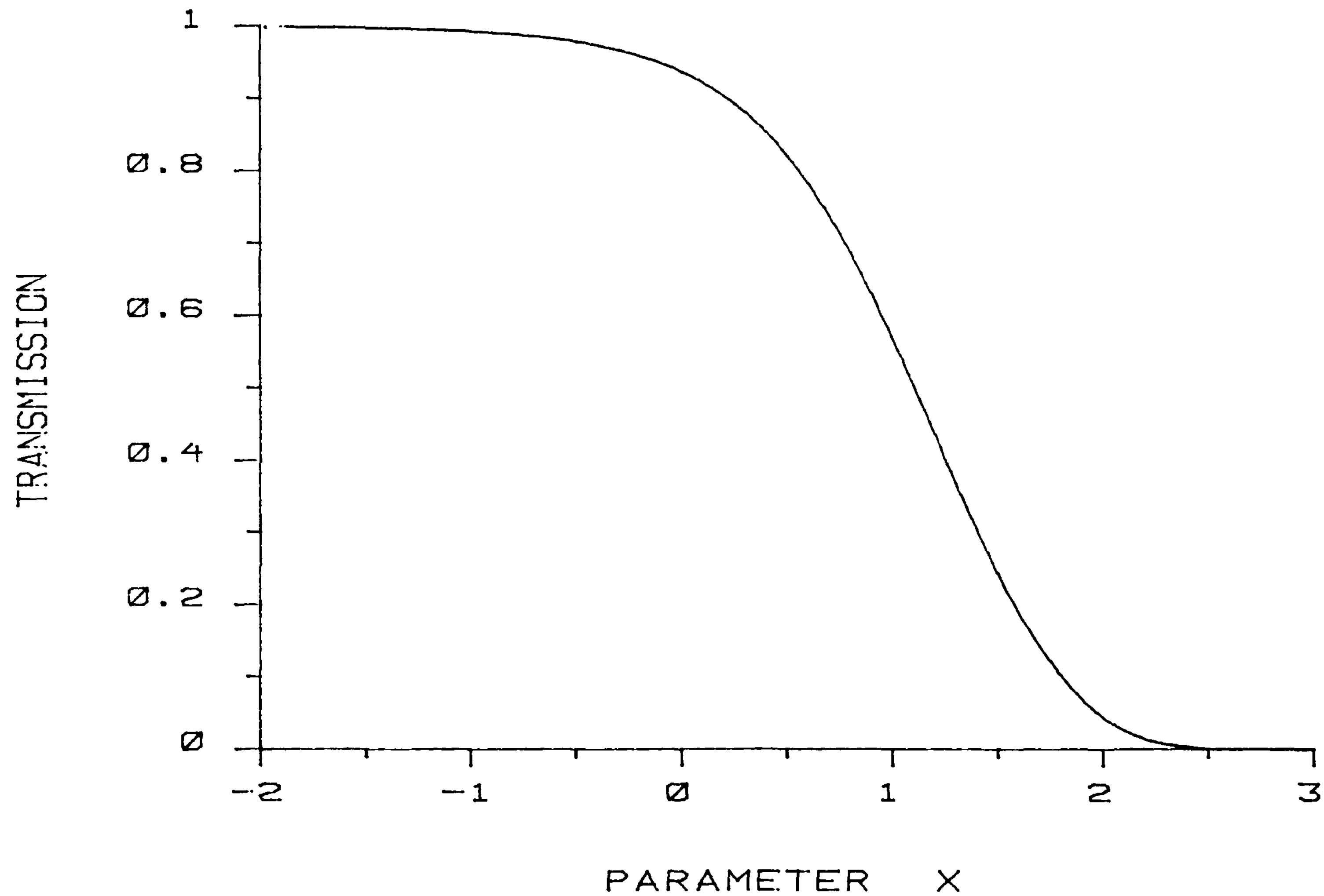

Fig. 9c. Empirical transmission function for NO_2.

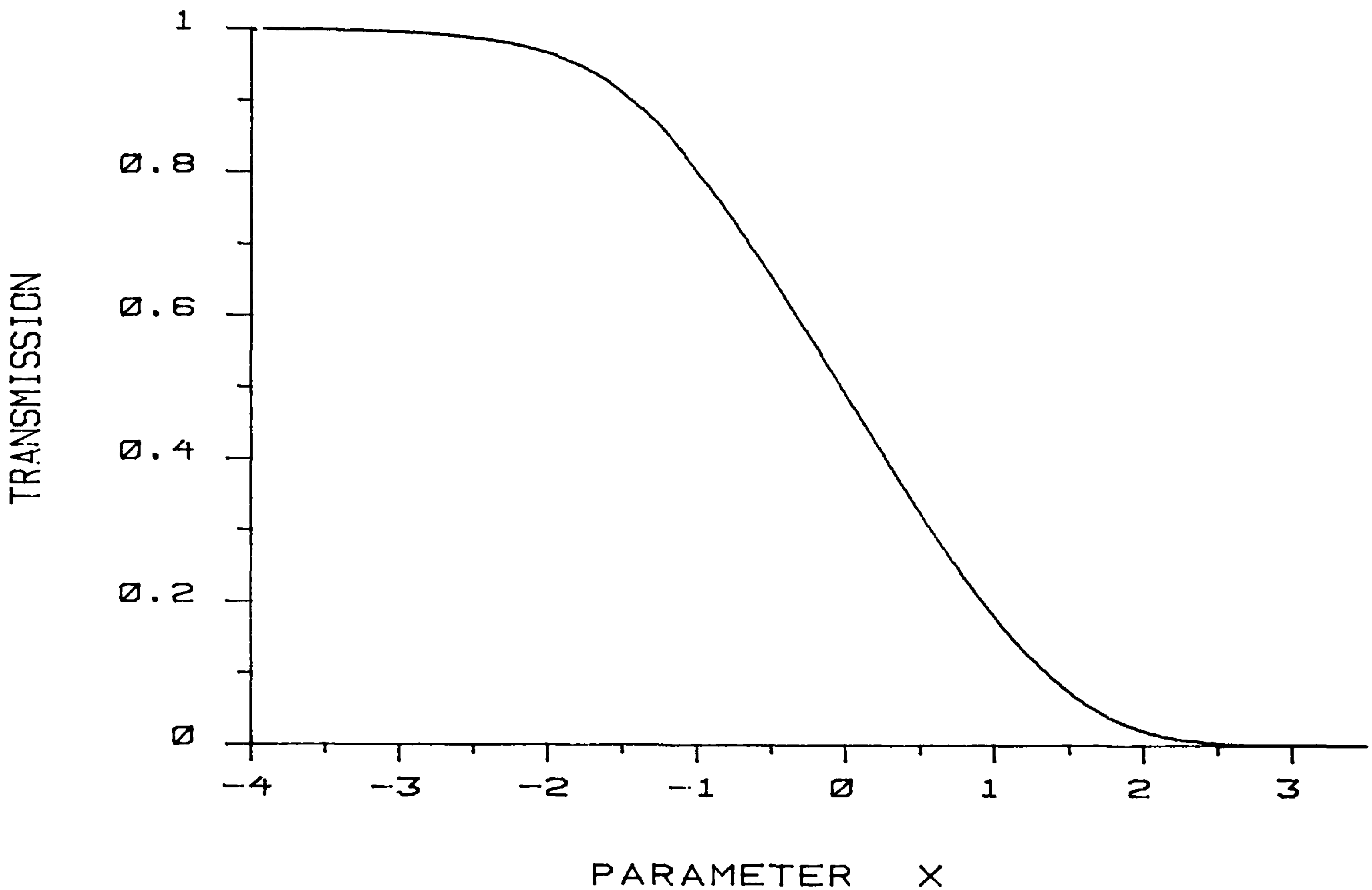

Fig. 9d. Empirical transmission function for NH_3.

VIII. Calculations and Results

8.1 Introduction

The procedure for the use of the Modularized Lowtran in calculations is identical to that of the original and, hence, deserves no further explanation. There are some input and output alterations that deserve some explanatory remarks. Changes in the input format include:

1. Reading of the spectral constants for all band models at the beginning of the main program rather than in the subroutines.
2. Elimination of the transmittance tables for H_2O vapor, infrared O_3 and the uniformly-mixed gases.
3. Reading of the spectral constants for the newly added band models for the trace gases.
4. Reading of the air density profile for the U.S. Standard atmosphere, and of the ppm for the calculation of the equivalent amounts of the trace gases.
5. Changes in the dimension statements to include the additional subscripted variables.

Changes in the output format include:

1. Modification of the print out of the input data.
2. Modification of the output table of computations to include the transmittance for the trace gases.

It should be stressed, however, that the code is operated using exactly the same four control cards as in the original code.

8.2 Testing of Modularized Version

The first step in the testing of the modularization consisted of running identical calculations using the original code and the modularized code before the replacement of the transmittance tables and before the addition of the trace gases. Numerous cases were considered during this effort. A particular case in which the spectral range varied from 2350 to 2450 cm^{-1} for a path at 65° from a height of 2.5 km to a height of 8.5 km and a 23 km visual range, is shown in the Appendix. This output is identical to the output obtained from the original Lowtran.

The second step in the testing procedure consisted of running calculations using the original code and the modularized version with the transmittance tables replaced with the continuous functions, but before the addition of the trace gases. For this purpose, 10 frequencies were selected such that different combinations of models would be effective in the calculation of the total transmittance. The calculations were for a 5 km path at sea level in a sub-arctic winter atmosphere with a 23 km visibility. The results are summarized in Table 9. The columns listed under Transmittance Deviations represent the differences between the calculations using the tabulated and the continuous functions. Note that the average total transmittance deviation is 0.0034, which is below the standard deviation obtained in the curve fitting of

TRANSMITTANCE DEVIATIONS

WAVENUMBER (cm^{-1})	H_2O VAPOR	INFRARED O_3	UNIFORMLY-MIXED GASES	TOTAL TRANSMITTANCE
455	0.0022	0.0000	0.0000	0.0021
555	0.0035	0.0000	0.0026	0.0018
655	0.0041	0.0003	0.0000	0.0000
755	0.0007	0.0003	0.0047	0.0038
955	0.0057	0.0002	0.0050	0.0096
1155	0.0026	0.0003	0.0050	0.0058
1355	0.0044	0.0000	0.0013	0.0006
1855	0.0007	0.0001	0.0034	0.0007
2455	0.0015	0.0000	0.0054	0.0045
3155	0.0037	0.0001	0.0027	0.0053

Table 9. Transmittance difference between calculations using the tabulation of the transmittance functions and calculations using the continuous function representation for a 5 km path at sea level in a sub-arctic winter atmosphere.

the functions to the individual transmittance tables. This deviation amounts to an error of about 0.7% in the middle of the curve-of-growth, which far exceeds the accuracy of Lowtran (between 10 to 20%). The following are attractive features of the continuous functions:

1. They inherently provide for continuous exponential interpolation in transmittance, which is superior to the linear interpolation used in connection with the transmittance tables.

2. They provide for analytical operations such as differentiation and interpolation often needed in radioactive transfer problems.

3. They can be used easily for curve fitting to new transmittance data using computerized procedures.

4. Their use reduces significantly the computer storage requirements for the individual models.

5. They continuously provide for transmittance calculations for small argument values where $0.9999 \leq \tau \leq 1$, for which range Lowtran 4 includes an additional exponential function.

It should be pointed out that the deviations listed in Table 9, although insignificant, do not represent errors solely attributed to the analytical functions. Since they are smaller than the uncertainties in the original data used to develop the tabulated transmittances, they primarily represent differences in the calculational procedures. In fact, in the region between the tabulations the use of the analytical functions are likely to provide more accurate results than the use of the original method in Lowtran.

The last effort in the testing of the modularized code consisted of calculations involving the newly added trace gases. For this purpose ten frequencies were run at which the trace gas models are effective. The same frequencies were run with the modularized Lowtran without these models. The results are summarized in Table 10. The table is primarily intended to show the absorptive effects of the trace gases.

MOLECULAR TRANSMITTANCE

WAVENUMBER (cm^{-1})	SO_2	NO	NO_2	NH_3	TOTAL (with T.G.)	TOTAL (without T.G.)
455	0.9948	1.0000	1.0000	1.0000	0.0000	0.0000
555	0.9308	1.0000	1.0000	1.0000	0.0185	0.0199
655	1.0000	1.0000	0.9997	1.0000	0.0000	0.0000
755	1.0000	1.0000	0.9995	0.9783	0.0029	0.0030
955	1.0000	1.0000	1.0000	0.8878	0.1155	0.1300
1155	0.8929	1.0000	1.0000	0.9820	0.1657	0.1890
1355	0.2728	1.0000	1.0000	1.0000	0.0000	0.0000
1855	1.0000	0.9034	1.0000	1.0000	0.0000	0.0000
2455	0.9998	1.0000	1.0000	1.0000	0.5734	0.5735

Table 10. Calculations of trace gas (T.G.) transmittances for a 5 km path at sea level in a tropical atmosphere with a 23 km visual range. The columns on total transmittance include all the attenuators and the trace gases, except for the rightmost column which excludes the trace gases.

Table 11: (a) Atmospheric regions included in the data calculations

Model	P (mbar)	T (°K)
Standard	1013	288.1
	898.6	281.6
	795.0	275.1
	701.2	268.7
	616.6	262.2
Tropical	805.0	288.0
Subarctic Winter	1013	257.1

(b) Transmitt. :e cuts chosen from the curve of growth

τ_1	0.99
τ_2	0.95
τ_3	0.9
τ_4	0.8
τ_5	0.7
τ_6	0.6
τ_7	0.5
τ_8	0.4
τ_9	0.3
τ_{10}	0.2
τ_{11}	0.1
τ_{12}	0.065

		Absorber Parameters		Spectral Parameter C' (cm^{-1})				Coefficients of Analytical Function	Standard Deviation
		n	m	ν_1 500	ν_2 1165	ν_3 1360	ν_4 2485		
	SIMMIN	0.07844	0.06037	0.0	0.019	1.108	-0.566	a_1 = 0.02292 a_2 = 0.86759 a_3 = -0.08578	0.006259
A D S E T	Band Model Parameters	0.07130	0.06186	0.0	0.014	1.104	-0.571		

A D S E T	Empirical τ_i =	0.95	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
	x_i =	-1.3727	-1.0569	-0.7246	-0.5140	-0.3498	-0.2076	-0.0742	0.0606	0.2115	0.4170	
	Piece-Wise Analytical (1st order) a_1 =	0.0682	0.0594	0.0492	0.0408	0.0343	0.0295	0.0273	0.0300	0.0466		
	a_2 =	0.9894	0.9811	0.9670	0.9506	0.9319	0.9091	0.8792	0.8353	0.7568		0.005749
	a_3 =	0	0	0	0	0	0	0	0	0		
	(2nd order) a_1 =	0.0755	0.2247	0.2099	0.1356	0.0590	0.0285	0.0299	0.0151	0.0296		
	a_2 =	1.0016	1.3653	1.5013	1.4061	1.1214	0.8897	0.8715	1.1520	0.8781		0.005604
	a_3 =	0.0050	0.2157	0.4314	0.5273	0.3400	-0.0689	-0.8641	-1.1634	-0.1931		

Table 12a. Band model parameters for SO_2.

	Absorber Parameters		Spectral Parameter C' (cm^{-1})				Coefficients of Analytical Function	Standard Deviation
	n	m	ν_1 1905	ν_2	ν_3	ν_4		
SIMMIN	1.05084	1.08785	0.0				$a_1 = -0.26287$ $a_2 = 0.58035$ $a_3 = -0.00926$	0.008667
Band Model Parameters	0.90099	1.01192	0.0					

A	Empirical											
	τ_i =	0.95	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
	x_i =	-1.5380	-1.1585	-0.6838	-0.3334	-0.0473	0.1988	0.4193	0.6260	0.8333	1.0715	
D	Piece-Wise Analytical											
S	(1st order) a_1 =	-0.0228	-0.1822	-0.2537	-0.2660	-0.2663	-0.2685	-0.2785	-0.3000	-0.3373	
	(1st order) a_2 =	0.8240	0.6364	0.5818	0.5450	0.5388	0.5497	0.5737	0.6080	0.6528	0.005563
E	(1st order) a_3 =	0	0	0	0	0	0	0	0	0	
T	(2nd order) a_1 =	-0.1770	-0.1867	-0.2710	-0.2709	-0.2615	-0.3293	-0.4937	-0.6837	-0.2321	
	(2nd order) a_2 =	0.5906	1.0667	0.5046	0.4258	0.6162	1.0007	1.4307	1.6815	0.4283	0.005635
	(2nd order) a_3 =	-0.0866	0.2064	-0.0759	-0.3133	-0.5107	-0.7296	-0.8199	-0.7357	0.1179	

Table 12b. Band model parameters for NO.

	Absorber Parameters		Spectral Parameter C' (cm^{-1})				Coefficients of Analytical Function	Standard Deviation
	n	m	ν_1 775	ν_2 1625	ν_3 2890	ν_4		
SIMMS	0.19941	0.22631	0.0	2.697	1.271		a_1 = -1.2203 a_2 = 1.0908 a_3 = -0.1188	0.015395
Band Model Parameters	0.17830	0.22484	0.0	2.689	1.259			

ADSEL												Standard Deviation
Empirical	[illegible] =	[illegible]	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
	[illegible] =	[illegible]	0.2140	0.5543	0.7739	0.9483	0.1028	1.2511	1.4046	1.5784	1.8074	
Piece-Wise Analytical (1st order)	a_1 =	-1.186[illegible]	-1.1324	-1.1656	-1.1404	-1.1052	-1.0604	-1.0042	-0.9381	-0.8656		
	a_2 =	0.9[illegible]70	0.9578	0.9276	0.8950	0.8579	0.8172	0.7723	0.7252	0.6793		0.015555
	a_3 =	0	0	0	0	0	0	0	0	0		
(2nd order)	a_1 =	-1.1864	-1.08[illegible]	-0.4268	0.0792	0.1053	-0.9289	-3.6587	-5.3854	-0.9659		
	a_2 =	0.9777	0.3013	-1.3600	-1.9671	-1.5164	0.5929	4.7838	6.7090	0.7984		0.015620
	a_3 =	-0.0065	0.8544	1.7222	1.6619	1.1576	0.0953	-1.5105	-2.0059	-0.0352		

Table 12c. Band model parameters for NO_2.

AD-A081 789 TEXAS UNIV AT EL PASO SCHELLENGER RESEARCH LABS F/G 7/4
COMPUTERIZED METHOD FOR THE GENERATION OF MOLECULAR TRANSMITTAN--ETC(U)
DEC 79 J H PIERLUISSI, K TOMIYAMA DAAG29-79-C-0067
UNCLASSIFIED FR1-79-UA-72 ARO-16641.1-GS NL

2 of 3
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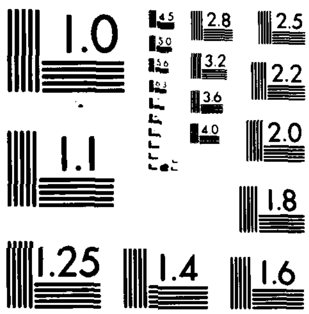
A081789



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

	Absorber Parameters		Spectral Parameter C' (cm^{-1})				Coefficients of Analytical Function	Standard Deviation
	n	m	ν_1	ν_2	ν_3	ν_4		
			930					
SIMMIN	0.58876	-0.71406	0.0				a_1 = -0.14141 a_2 = 0.44740 a_3 = -0.06716	0.010536
ADSET: Band Model Parameters	0.52125	-0.60437	0.0					

ADSET											Standard Deviation
Empirical	τ_i =	0.95	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
	x_i =	-1.8032	-1.4438	-1.0054	-0.6608	-0.3403	-0.0330	0.2673	0.5751	0.9210	1.3562	
Piece-Wise Analytical (1st order)	a_1 =	0.2775	0.0962	-0.0570	-0.1261	-0.1450	-0.1459	-0.1409	-0.1290	-0.1224		
	a_2 =	0.8692	0.7436	0.5913	0.4867	0.4312	0.4037	0.3852	0.3645	0.3573		0.005237
	a_3 =	0	0	0	0	0	0	0	0	0		
(2nd order)	a_1 =	0.0894	0.9846	0.2095	-0.1135	-0.1475	-0.1419	-0.2291	-0.3829	-0.0196		
	a_2 =	0.6347	2.2425	1.2594	0.5427	0.3457	0.5098	0.8682	1.0318	0.1698		0.005484
	a_3 =	-0.0722	0.6120	0.4010	0.0559	-0.2290	-0.4530	-0.5734	-0.4794	0.0785		

Table 12d. Band model parameters for NH_3.

8.3 Band Model Development

Two sets of curves of growth data for each major absorption band for four trace gases SO_2 NO, NO_2, and NH_3 were generated by the line-by-line calculation from the AFGL trace gas parameter tape. One of them consists of 12-cut data for several layers of atmosphere and the other consists of 65-cut data for the standard atmosphere only. Considering the wide range of applications, we included not only the standard atmospheric conditions but also one condition each from the tropical and subarctic winter climates. They are listed in Table 11 together with the 12 chosen transmittance values. The major absorption bands for the four trace gases are given in Table 12 together with the corresponding computed C' values.

Ten middle cuts were chosen from the 12-cut data and used in both ADSET and SIMMIN for the computation of the band model parameters and the standard transmission function. Depending on the number of major absorption bands, the total numbers of data used differ but are in the range of 60-210. The 65-cut data was used in ADSET for the piecewise interpolation to compute piecewise analytical transmission functions.

The ADSET computations were done first. The obtained band model parameter values n, m, and C_1' and nine sets of coefficients a_1, a_2, and a_3 are tabulated in

Table 12 for SO_2, NO, NO_2, and NH_3 in this order. The corresponding standard deviations are also listed in these tables.

We also have generated standard atmospheric condition data for non-major bands of each trace gases. These data were used to evaluate non-major $C'(\nu)$ values. The computed $C'(\nu)$ values were listed in Table 5. As we have discussed, these $C'(\nu)$ values and the band model parameters together with the first order piecewise-analytical standard transmission function were implemented in the modularized Lowtran.

We recall that the SIMMIN computation is a recursive one and we need a set of initial guesses of the parameter values to start the computation. For the band model parameters n, m, and C_i', we used the values computed by ADSET. For a_1 and a_2, the respective averages of the first order piecewise interpolation results of ADSET were used. Finally, a_3 was set to be zero. We note that our initial guesses are fairly accurate, since these values were optimal or optimal in average for ADSET computation. A small number ε which was used for the check of convergence was chosen to be 10^{-6}. Since the parameter values are expected to be in the range -10~10, $\varepsilon = 10^{-6}$ gives the limit of numerical accuracy of numbers in the computer. The SIMMIN results are also listed in Table 12.

Typical curve-fits by piecewise analytical standard transmission functions to actual data are shown in Fig. 10 for SO_2 at 500 wavenumber. The corresponding analytical standard transmission function are also compared to the data in Fig. 10. In all of the three graphs in this Figure, the 65-cut data were also plotted to show the fitness of the standard curves.

The computation was repeated using two smaller data sets with 6 and 4 cuts only. The chosen cuts were (0.95, 0.9, 0.8, 0.6, 0.4, and 0.1) for 6 cut data and (0.95, 0.9, 0.6, and 0.2) for 4 cut data. The derived band model parameter values were similar to those in Table 12 and, hence, were not repeated here. Instead, the corresponding standard deviations were listed and compared with the 10 cut cases in Table 13.

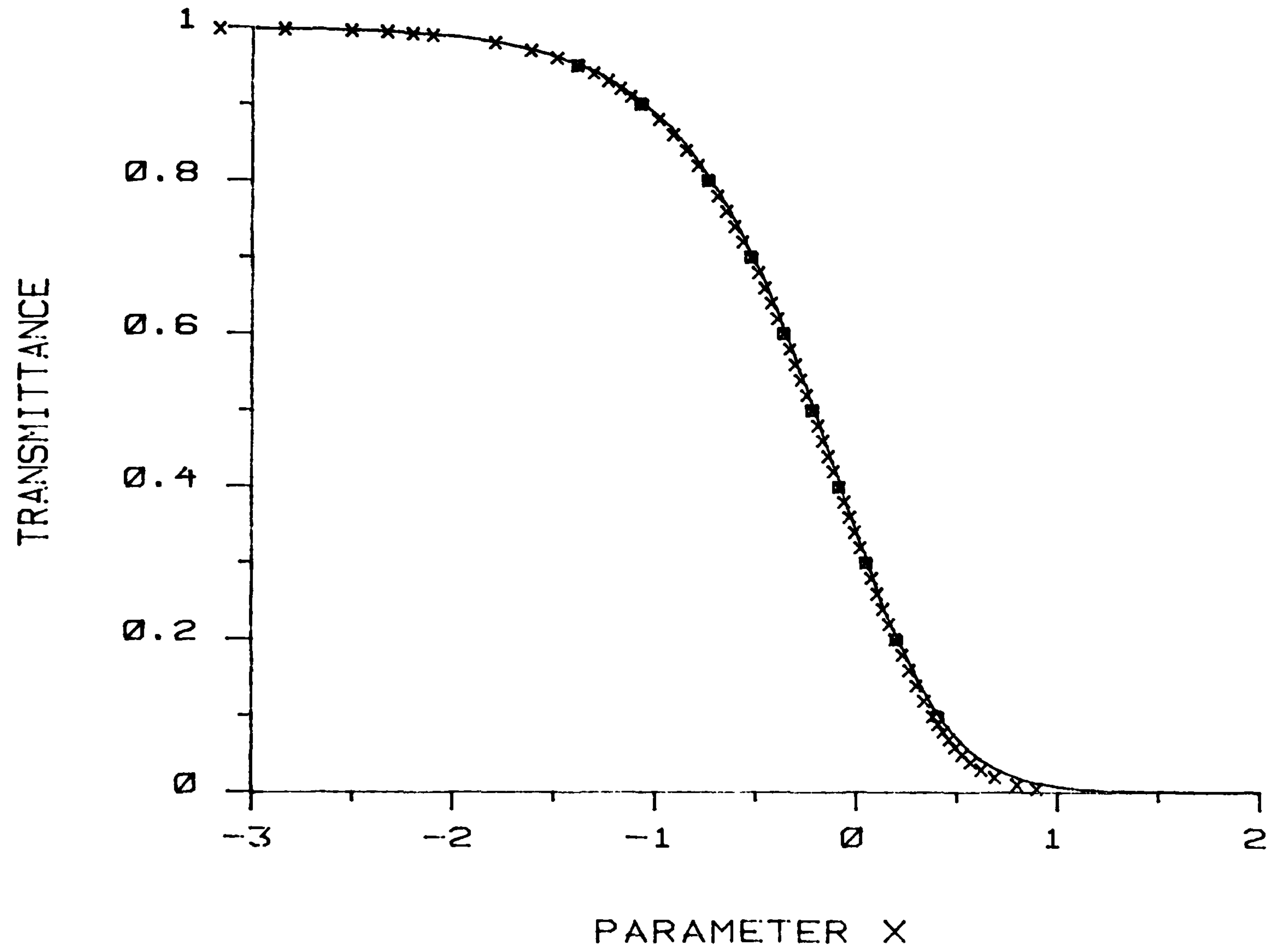


Fig. 10. (a) Standard transmission function from ADSET with a_3 = 0 for SO_2 at 500 cm^{-1}

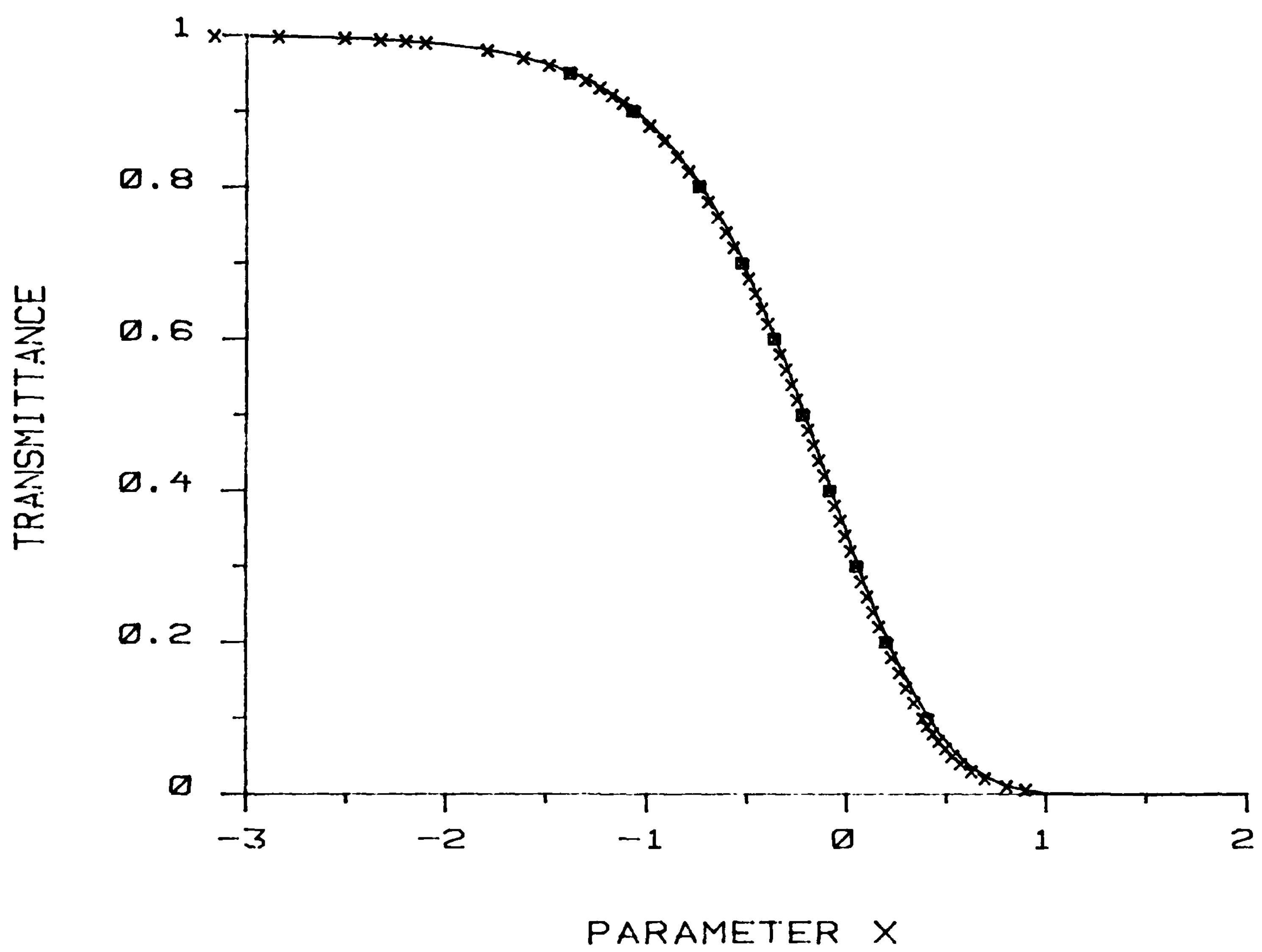


Fig. 10. (b) Standard transmission function from ADSET with $a_3 \neq 0$ for SO_2 at 500 cm^{-1}

ADSET $a_3 \neq 0$
— piecewise analytic
Ø empirical
x 65 data

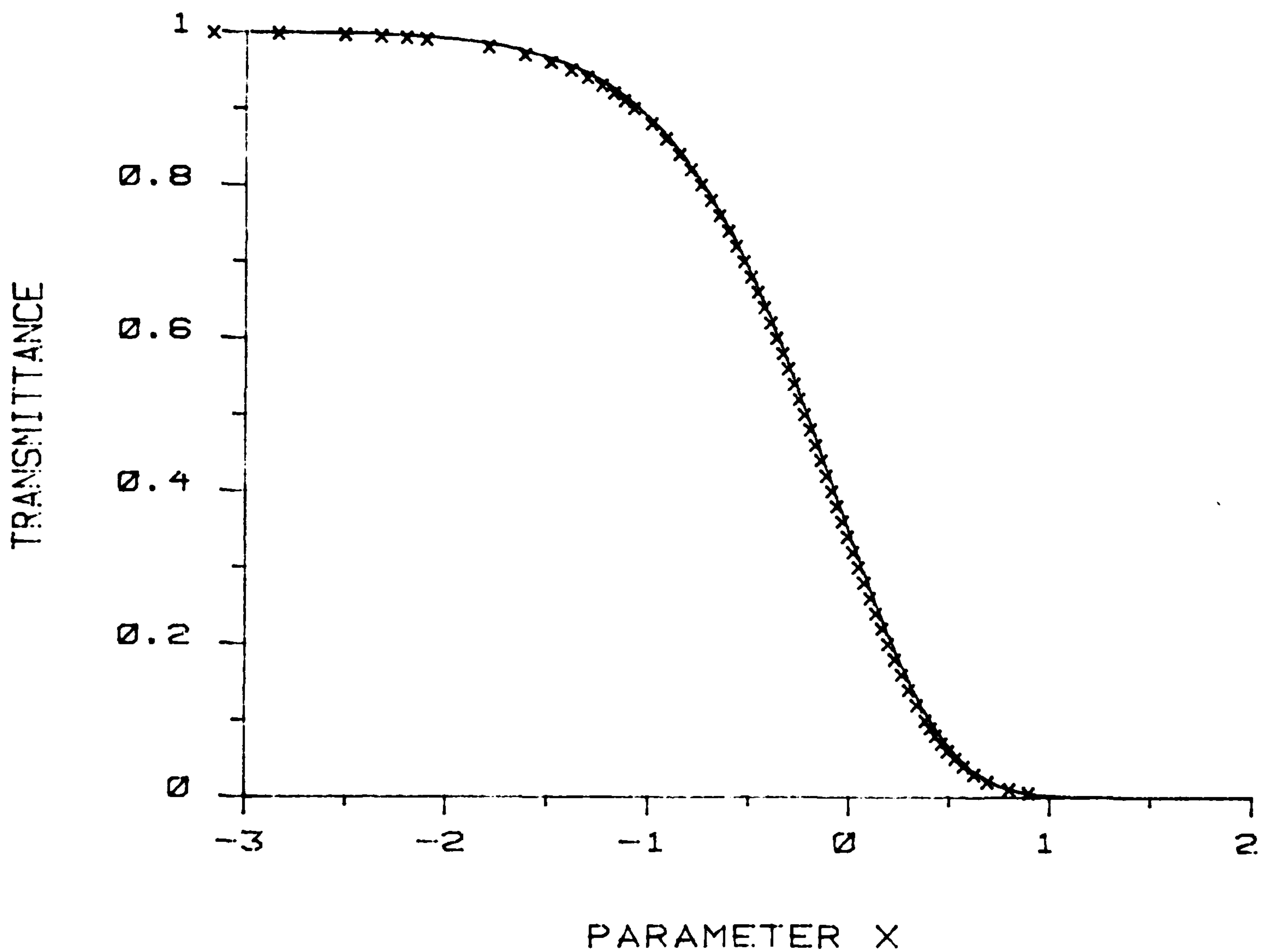


Fig. 10. (c) Standard transmission function from SIMMIN for SO_2 at 500 cm^{-1}

ABSORBER	CODES		STANDARD DEVIATIONS IN τ		
			4 Cut Data	6 Cut Data	10 Cut Data
SO_2	SIMMIN		0.004450	0.006636	0.006259
	ADSET	1	0.005344	0.006551	0.005749
		2	0.004830	0.006036	0.005604
NO	SIMMIN		0.005349	0.009345	0.008667
	ADSET	1	0.009310	0.006934	0.005563
		2	0.009210	0.006764	0.005635
NO_2	SIMMIN		0.015009	0.014051	0.015395
	ADSET	1	0.01863	0.015355	0.015555
		2	0.017377	0.014780	0.015620
NH_3	SIMMIN		0.004661	0.010423	0.010558
	ADSET	1	0.006455	0.005454	0.005237
		2	0.006594	0.005400	0.005484

Table 13. Comparison of standard deviations in τ. The two rows, ADSET 1 and 2 are, respectively, for the piecewise analytical transmission functions and linear and quadratic exponents.

IX Discussion and Conclusions

9.1 Introduction

The modularized version presented here is fundamentally the same Lowtran code except for the separation of its computation structure into separate modules or subroutines. Although it is based on the 4th version, it can be adapted with little modification to any future versions, such as the 5th version now in progress. In fact, this latter version already has been structured by AFGL such that the emission/radiance loop is in a subroutine. The modularized code presented here breaks down that loop into a frequency selection subroutine, an equivalent absorber amount subroutine and separate subroutines for each one of the attenuation codes. The use of modules in a complex code such as Lowtran has numerous advantages, among which the amenability for updating by individual users to suit their specific needs is at the top of the list. In the ever changing field of modeling it is highly desirable to be able to easily modify the code for changes in the spectral coverage, the spectral resolution, the absorber concentrations in abnormal environments, the original transmission data used in the development and in the models used for the individual attenuators. The modularized version presented here, although is not the final answer to all conceivable needs, it is a first basic step

in that direction. Practicing this predicament, the authors added transmission models for the trace gases to the code.

9.2 Changes and Recommendations

The following are the basic changes introduced in The Modularized Lowtran:

1. The original main program was separated into a central program and subroutines for the absorber amount and the individual attenuation models.

2. In the interest of efficiency and clarity, a new subroutine FGQSL was added for the selection of the attenuation model effective at the given frequency.

3. The subroutine HNO_3 was re-structured to the form of the other previously incorporated subroutines in Lowtran.

4. Continuous analytical models were provided to replace the transmittance curves for H_2O vapor, O_3 and the uniformly-mixed gases.

5. New subroutines for the trace gases SO_2, NO, NO_2 and NH_3 were added.

A copy of the modularized version is found in the Appendix.

Some recommendations may be made at this time concerning future modifications of Lowtran. They are as follows:

1. AFGL should be informed of the modularization presented here as well as of the addition of the trace gases (SO_2, NO, NO_2 and NH_3) so that they may modify their master copy accordingly.

2. As soon as they are available, vertical profiles for the concentrations of the trace gases should be added.

3. The uniformly-mixed gases (CO_2, N_2O, CO, CH_4, etc.) should be modeled and be included as separate subroutines.

4. The resolution of all resonant absorption models in the IR should be increased to about 10 cm^{-1}, which will also allow for model redevelopments with more recent and more accurate transmission data.

5. All model developments should adopt computerized numerical methods rather than the inaccurate manual graphical techniques used in the past.

6. The transmittance calculations should include the calculation of the standard deviation expected from known uncertainties in the input meteorological variables[12-14].

7. The slant-path calculations should include corrections for the Lorentzian-Doppler broadening above the 10 mb-level.

8. Continuous functions should replace the tabulated transmittance functions, together with their awkward interpolation procedure.

9.3 Model Development

The values of band model parameters n and m and spectral parameters C_i' obtained by ADSET and SIMMIN agreed very well. Furthermore, as it was shown in Table 13, the standard deviations corresponding to different cases followed a same pattern for the ADSET and SIMMIN results. This consistency proves the validity of both methods.

In general, the SIMMIN and ADSET computations resulted in similar standard deviations. It was expected that the ADSET computation should result in lower standard deviations since it contained more parameters to adjust. However, for a half of the cases, the SIMMIN code produced lower standard deviations. This is due to the large computational error for the ADSET computations in solving the normal equation AX = B. When the condition number of the coefficient matrix A becomes large (i.e., A becomes close to be singular), the computational error becomes so large that it can exceed the directly minimized error of the SIMMIN computation.

We note that this reversal occurred for all four cut data cases. This suggests that the advantage for ADSET of having more parameters to be adjusted is not significant for these cases. Hence, we recommend the use of SIMMIN if the available data contains less than five or six cuts.

A comparison of the standard deviations for two

piecewise interpolation results in the ADSET computation showed no significant difference. Furthermore, the results with the second method using quadratic form of x on the exponent of the double exponential function were 'bumpy' for some cases. Since the nature of the transmittance does not predict this behavior, we conclude that the first method using linear function of x is accurate enough to be used in the actual application.

The standard deviations were much higher for NO_2 cases than the cases for the rest of absorbers. By inspecting each curve of growth in detail, it was found that this was mainly due to the difference in the steepness of the curves of growth for three absorption bands. This difference cannot be compensated by C_i' values since they only shift the curves of growth linearly. In fact, within the current band model structure, it is impossible to compensate this difference. Hence, it may be necessary to modify some of the basic assumptions regarding the band model structure, if lower standard deviations are required.

As a side-effect of this discrepancy in the tangent of curves of growth, the SIMMIN computation took far more time for NO_2 cases than the rest. Most of the computations of ADSET were completed by 26-36 CPU seconds. The fluctuations in the computation time were very small. On the other hand, the SIMMIN computation time varied from 14 seconds to 270 seconds. NO_2 cases consumed about 200-270

seconds, which were about four times as much as that for the other cases. This is because the minimizing point in the parameter space is not well defined for NO_2 cases. In other words, the error surface in the parameter space has a very shallow bottom so that the updating step cannot produce large enough changes in the parameter guesses in order to have a rapid convergence.

Thus, it was found that the accuracy of the computed results and the time of execution depend heavily on the actual data. Hence, it is very important to give enough consideration for the data structure. This will be discussed in the next section.

9.4 Data Structure

As it was expressed earlier, we assumed that the number of layers (= the number of data points) in each cut is the same for an absorption band. This was done for the sake of easier coding in data handling. However, this assumption need not be valid. Especially in weaker absorption bands, it is required to use very large range values to have high enough equivalent absorber amounts in order to realize lower transmittances. In some cases the range becomes enormous (in the order of the radius of the earth) so that the corresponding data no longer possess physical significance. The ADSET code has a criterion that if the logarithm of the equivalent absorber, log W, exceeds a certain critical value, then the corresponding data will be set aside and will not be used in the later computation. The critical value was set to be 2 for the actual computation, which corresponds approximately to a vertical path through the atmosphere.

In connection with this, if data are not available at some layers, then the data values are set at 0 to flag the nonavailability of data. ADSET can also detect this and will ignore the data.

A caution must be executed in choosing combinations of pressures and temperatures, i.e., atmospheric conditions. If a data set contains either the standard pressure or the

standard temperature or both only, then both ADSET and SIMMIN fail because of the fact that the coefficient of n or m or both in Eq.(12) becomes zero, since

$$\log\left(\frac{P_o}{P_o}\right) = \log 1 = 0, \tag{61}$$

$$\log\left(\frac{T_o}{T_o}\right) = \log 1 = 0. \tag{62}$$

For this case, the coefficient matrix A of the normal equation in ADSET becomes singular and the gradient corresponding to n or m or both in SIMMIN becomes zero all the time. Hence, the normal equation cannot be solved in ADSET and the initial guess of n or m or both cannot be changed in SIMMIN.

Another consideration which should be pointed out is to include different climate conditions. The standard climate condition for several layers of atmosphere contains sequence of pressures and temperatures both of which are monotone decreasing. Therefore, if only these conditions are used, then it is very difficult to distinguish the cause of changes in the transmittance due to the changes in pressure and in temperature. This leads to the shallow bottom of the error surface and hence, large computational error results in ADSET caused by the large condition number of the coefficient matrix and slow convergence in SIMMIN due to the small gradient. In the actual computation,

we included not only the standard climate conditions but also one condition each from the tropical and subarctic winter climates in consideration of wide applicability of the results. Numerically speaking, this also resulted in making the regression problem well-posed by breaking the monotonousness of the pressure and temperature combinations of the standard conditions. In fact, several computations were done for ADSET and SIMMIN with standard condition data only. SIMMIN took 10-45 minutes of CPU time to converge if it were convergent and ADSET resulted in a set of absurd values for n and m. Thus, the importance of the numerical consideration, which is ignored in many cases, is clearly indicated. The proper care should be taken when selecting controllable data values.

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```
0001        COMMON /MO1/ Z(34),P(7,34),T(7,34),EH(15,34),WH(7,34),M,NL,RE,CA,C
           1O,21,WA(7,34)
0002        COMMON /MO2/ IFIND,CA,IP,JSTOP
0003        COMMON /MO3/ HZ1(34),HZ2(6),WC(7,34)
0004        COMMON /MO4/ IHAZE,JP,IM,M1,M2,M3,ML,RO,TBOUND
0005        COMMON /MO5/ C1(2590),C2(1575),C3(540),C4(133),C5(15),C8(102),C11(
           144),C12(115),C13(43),C14(109),C15(85)
0006        COMMON /MO6/ VX(45),C7(45),C7A(45)
0007        COMMON /MO8/ SUM4,SUM5,SUM6,SUM7,SUM8,SUM11
0008        COMMON /MO9/ RADMAX,RADMIN,VEMAX,VEMIN
0009        COMMON /MO10/ FS(9),S1(9),S2(9)
0010        COMMON /MO11/ FN0(9),FN1(9),FN2(9)
0011        COMMON /MO12/ FNH3(9),FH1(9),FH2(9)
0012        COMMON /MO13/ FNO2(9),J1(9),J2(9)
0013        COMMON /MO14/ PPMSO2,PPMNO,PPMNH3,PPMNO2
0014        DIMENSION WPATH(68,15),TRAY(68),WLAY(34,15),HZ(2),TX(15),HMIX(34)
0015        DIMENSION TX9(20),TX12(20),TX13(20),TX14(20),TX15(20),SUMAC(20)
0016        COMMON /EM1/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE
0017        COMMON /EM2/ IL,IKMAX,LENTRE,NLL,W(15),E(15)
0018        COMMON /EM3/ H1,H2,R21,MODEL
      C HMIX(I)=HNO3 VOLUME MIXING RATIOS TIMES E+09 FROM EVANS PROFILE
0019        DATA HMIX/3*0.,0.1,0.33,0.6,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3.
           17,4.2,5.2,6.0,3.8,2.5,0.22,6*0.0/
      C     PLANCK RADIANCE FUNCTION .........
0020        FF(T,V)=1.190956E-16*(V**5)/(EXP(1.43879*V/T)-1.)
      C       MILLIWATTS. CM-2 ST-1 MICRON-1
0021        F(A)=EXP(18.9766-14.9595*A-2.43832*A*A)*A
0022        DATA HZ(1)/4H23KM/,HZ(2)/4H5 KM/
      C*****************************************************************
      C
      C     MODULARIZED LOWTRAN4: THIS VERSION WAS MODULARIZED BY THE
      C     UNIVERSITY OF TEXAS AT EL PASO FOR THE ATMOSPHERIC SCIENCES LAB.
      C     BY J.H. PIERLUISSI AND S.Y. LIN IN JULY 1979. IT SEPARATES LOWTRAN
      C     INTO MODULES FOR INDIVIDUAL 13 ATTENUATORS, FREQUENCY SELECTION,
      C     AND EQUIVALENT ABSORBER AMOUNT. MODELS FOR THE TRACE GASES SO2,NO,
      C     NO2,NH3 HAVE BEEN ADDED.
      C
      C     PROGRAM MODULARIZED LOWTRAN4 CALCULATES THE TRANSMITTANCE OF THE
      C     ATMOSPHERE FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT
      C     20 CM-1 SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.
      C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.    ATMOSPHERE
      C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER-
      C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.
      C     INTERVAL TO 100 KM.
      C*****************************************************************
      C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS
      C
      C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO  FORMAT(10I3,F10.3)
      C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS                   FORMAT(7F10.3)
      C   CARD 3 V1, V2, DV                                   FORMAT(7F10.3)
      C   CARD 4 IXY                                          FORMAT(I3)
      C
      C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE
      C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,
      C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY
      C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED:INSTEAD OF CARD 2
      C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),REL HUMIDITY,H2O DENSIT
0023        HMIX(29)=1.0E-50
```

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FORTRAN IV G LEVEL  21              MAIN              DATE = 79213          16/22/49              PAGE 0002

                C      (GM,M=3),O3 DENSITY(GM,M=3), VIS(KM),RANGE(KM) WITH FORMAT 103 IN
                C      SUBROUTINE AERSOR4.
                C      MODEL=7 WHEN NEW MODEL ATMOSPHERE (E.G. RADIOSONDE DATA) USED.
                C      DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN:
                C      ALTITUDE(KM,),PRESSURE,TEMP,DEW PT,TEMP,REL. HUMIDITY,H2O DENSITY,
                C      O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 103 IN
                C      SUBROUTINE AERSOR3.
                C      NOTE THAT EITHER DEW PT. TEMP. OR REL. HUMIDITY CAN BE USED.
                C
                C      M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.
                C         IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE
                C         TBOUND=TEMPERATURE OF EARTH IN DEGREES KELVIN
                C         IF TBOUND=ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.
                C
                C      IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED
                C      IHAZE=1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN
                C      CONJUNCTION WITH VISUAL RANGE (SEE CARD 2))
                C      IHAZE= 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS.
                C      HAZE MODELS RESPECTIVELY IF VIS=0 ON CARD 2
                C      IHAZE= 7 FOR OTHER AEROSOL MODELS (E.G. MARITIME ETC) WHICH ARE
                C      READ INTO PROGRAM
                C
                C      ITYPE= 1,2 OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH
                C      ITYPE = 3, VERTICAL OR SLANT PATH TO SPACE
                C      ITYPE = 2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES
                C      ITYPE = 1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH
                C
                C      H1 = OBSERVER ALTITUDE (KM)
0024                   HMIX(8)=HMIX(29)
                C      H2 = SOURCE ALTITUDE (KM)
                C      ANGLE = ZENITH ANGLE AT H1 (DEGREES)
                C      RANGE = PATH LENGTH (KM)
                C      BETA = EARTH CENTRE ANGLE
                C      VIS = VISUAL RANGE AT SEA LEVEL (KM)
                C      ( IF ITYPE=1 READ H1 AND RANGE; IF ITYPE=3 READ H1 AND ANGLE;
                C      IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)
                C
                C      V1 = INITIAL FREQUENCY (WAVENUMBER CM-1) INTEGER VALUE
                C      V2 = FINAL FREQUENCY (WAVENUMBER CM-1) INTEGER VALUE
                C      DV = FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
                C      NOTE: DV MUST BE A MULTIPLE OF 5 CM-1
                C
                C      IXY = 0 TO END DATA, = 1 FOR NEW V1,V2,DV ONLY, = 2 TO CONTINUE
                C      DATA, = 3 FOR NEW CARD 2 ONLY, = 4 FOR NEW CARD 1 ONLY.
                C*********************************************************************
0025                   IXY=0
0026                   KMAX=15
0027                   READ (5,100) IATM,NL
0028                   READ (5,101) (HZ1(I),I=1,NL)
0029                   READ (5,101) (HZ2(I),I=1,5)
0030                   HZ2(6)=HZ1(6)
0031                   DO 1 J=1,3
0032                   K2=2*J
0033                   K1=K2-1
0034                   DO 1 I=1,NL
0035            1      READ (5,102) Z(I),(P(K,I),T(K,I),WA(K,I),WH(K,I),WO(K,I),K=K1,K2)
0036                   READ (5,132) PPMSO2,PPMNO,PPMNH3,PPMNO2
0037                   READ (5,103) (VX(I),C7(I),C7A(I),I=1,44)
```

```
      READ (5,105) (C1(I),I=1,253)
      READ (5,105) (C2(I),I=1,157)
      READ (5,105) (C3(I),I=1,54)
      READ (5,106) (C4(I),I=1,133)
      READ (5,105) (C5(I),I=1,15)
      READ (5,106) (C8(I),I=1,102)
      READ (5,107) (C11(I),I=1,44)
      READ (5,124) (C12(I),I=1,115)
      READ (5,125) (F5(I),S1(I),S2(I),I=1,9)
      READ (5,126) (C13(I),I=1,43)
      READ (5,126) (C14(I),I=1,109)
      READ (5,126) (C15(I),I=1,85)
      READ (5,127) (FN3(I),FN1(I),FN2(I),I=1,9)
      READ (5,127) (FNH3(I),FH1(I),FH2(I),I=1,9)
      READ (5,127) (FNO2(I),.1(I),.2(I),I=1,9)
      C5(11)=0.
      C5(12)=0.
      C5(13)=0.
      C5(14)=0.
      C5(15)=0.
      JSTOP=0
      PI=3.14159265
      CA=PI/180.
      IP=0
    2 CONTINUE
      RE=6371.23
      IEND=0
      READ 100,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
      IF(IEMISS.EQ.1) PRINT 104
      IF(IEMISS.EQ.0) PRINT 109
      LENTOP=LEN
      PRINT 100,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
    3 M=MODEL
      IF (M.EQ.1) RE=6378.39
      IF (M.EQ.4) RE=6356.91
      IF (M.EQ.5) RE=6356.91
      IF (IHAZE.NE.7) GO TO 4
      READ 103,(VX(I),C7(I),C7A(I),I=1,4.)
      PRINT 103,(VX(I),C7(I),C7A(I),I=1,4.)
      IHAZE=1
    4 IF (RO.GT.0) RE=RO
    5 CALL ASSIGN(IKY,LENTOP,HZ,HMIX,.,TX,V1,V2,DV,ALAM,SUMA,WLAY)
    6 WRITE (6,110)
      WRITE(6,112) (X(I),I=1,.)
      WRITE (6,111)
      WRITE (6,128) (X(I),I=1,.)
      I=1
      L=1
      IV1=V1/5.0
      IV2=V2/5.+.99
      IV1=5*IV1
      IV2=5*IV2
      IF (IV1.LT.35)) IV1=35)
      IF (IV2.GT.50000) IV2=50000
      IF (DV.LT.5.) DV=5.
      IDV=DV
      IV=IV1-IDV
      NX=0
```

```
            ICOUNT=0
            IF(IEMISS.EQ.0) GO TO 7
            RADSUM=0.0
            FACTOF=0.5
            CALL PATH(WLAY,WPATH,TEBY)
            PRINT 113
            PRINT 114
            IF(IEMISS.EQ.0) IKMAX=IKLO
      C**** BEGINING OF TRANSMITTANCE CALCULATIONS
      7     IV=IV+IDV
            NX=NX+1
            SUMV=0.
            TLOLD=1.
            TSOLD=1.
            IKLO=1
            IF(IEMISS.EQ.0) IKLO=IKMAX
            DO 17 IK=IKLO,IKMAX
            IF(IEMISS.EQ.0) GO TO 9
            DO 8 K=1,KMAX
            W(K)=WPATH(IK,K)
      8     CONTINUE
      9     IJ=IK
            IF(JP.NE.0) GO TO 11
            IF (ICOUNT.EQ.0) GO TO 10
            IF (ICOUNT.EQ.50) GO TO 10
            GO TO 11
      10    ICOUNT=0
            IF(IEMISS.EQ.0) PRINT 115
      11    DO 12 K=1,KMAX
            TX(K)=1.0
      12    CONTINUE
            ICOUNT=ICOUNT+1
            V=IV
            I=(IV-350)/5+1
            SUM4=0.
            SUM5=0.
            SUM6=0.
            SUM7=0.
            SUM8=0.
            SUM11=0.
            CALL FRFOSL(I,IV,W,IHAZE,TX,ALAM)
            TX(9)=SUM4+SUM5+SUM6+SUM7+SUM8+SUM11
            IF (TX(9).EQ.0.0) GO TO 14
            IF(TX(9).LE.0.1) GO TO 13
            IF (TX(9).GT.20.) GO TO 15
            TX(9)=EXP(-TX(9))
            GO TO 16
      13    TX(9)=1.0-TX(9)+0.5*TX(9)*TX(9)
            GO TO 16
      14    TX(9)=1.0
            GO TO 16
      15    TX(9)=0.
      16    TX(9)=TX(1)*TX(2)*TX(3)*TX(9)*TX(12)*TX(13)*TX(14)*TX(15)
            IF (IV.GE.13000) TX(3)=TX(8)
            IF(IEMISS.EQ.0) GO TO 19
            ALAM=1.0E+04/V
            BBIK=FF(TBBY(IK),V)
            TLJFW=(TX(9)*TX(10))/(TX(7)*TX(6))
```

```
            TSNEW=(TX(7)*TX(6))/TX(10)
            DTAU=TLOLD-TLNEW
            IF (DTAU.LT.1.0E-5.AND.TLNEW.LT.1.0E-5) GO TO 18
            SUMV=SUMV+0.5*BBIK*DTAU*(TSOLD+TSNEW)
            TLOLD=TLNEW
            TSOLD=TSNEW
   17       CONTINUE
   18       CONTINUE
            TAUS=0.
            IF(HMIN.LE.0.0.AND.IL.EQ.1) TAUS=TX(9)
            T1=T(M,1)
            IF(TBOUND.GT.0.0) T1=TBOUND
            ARG=FF(T1,V)*TAUS
            IF (HMIN.LT.0) SUMV=SUMV+ARG
            SUMVV=SUMV
            IF (IV.GT.IV1) FACTOR=1.0
            IF (IV.GE.IV2) FACTOR=0.5
            SUMV=(1.0E+04/V**2)*SUMV
            RADSUM=RADSUM+DV*FACTOR*SUMV
            IF(JP.EQ.0) PRINT 115, V,ALAM,SUMV,SUMVV,RADSUM,TX(9)
            IF(SUMV.GE.RADMAX) VRMAX=V
            IF(SUMV.GE.RADMAX)  RADMAX=SUMV
            IF(SUMV.LE.RADMIN) VRMIN=V
            IF(SUMV.LE.RADMIN) RADMIN=SUMV
   19       TX(10)=1.-TX(10)
            AB=1.-TX(9)
            IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
            SUMA=SUMA+AB*DV
            IF(IEMISS.EQ.1) GO TO 20
            SUMAC(NX)=SUMA
            TX12(NX)=TX(12)
            TX13(NX)=TX(13)
            TX14(NX)=TX(14)
            TX15(NX)=TX(15)
            TX9(NX)=TX(9)
            IF(JP.EQ.0) WRITE(6,118) IV,ALAM,(TX(K),K=1,7),TX(10)
   20       CONTINUE
            IF (IV.GE.IV2) GO TO 26
            GO TO 7
   26       IV=IV1-IDV
            NX=0
            WRITE(6,129)
   27       IV=IV+IDV
            V=IV
            ALAM=1.0E+04/V
            NX=NX+1
            WRITE(6,130)  IV,ALAM,TX12(NX),TX13(NX),TX14(NX),TX15(NX),SUMAC(NX
           1),TX9(NX)
            IF(IV.GE.IV2) GO TO 21
            GO TO 27
   21       READ 100, IXY
            IF(IEMISS.EQ.1) PRINT 119,VRMIN,RADMIN,VRMAX,RADMAX
            JSTOP=0
            IFIND=0
            AB=1.0-SUMA/(V2-V1)
            PRINT 120, IV1,IV2,SUMA,AB
            IF(IEMISS.EQ.1) PRINT 121,RADSUM
            PRINT 100,IXY
```

```
0210              IF(IXY.EQ.0) GO TO 25
0211              GO TO (22,2,23,24,25),IXY
0212        22    READ 122, V1,V2,DV
0213              AVW=10000./V1
0214              ALAM=10000./V2
0215              PRINT 123, V1,V2,DV,ALAM,AVW
0216              SUMA=0.0
0217              GO TO 6
0218        23    IF(MODEL.EQ.0) GO TO 3
0219              GO TO 5
0220        24    READ 100,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
0221              IF(IEMISS.EQ.1) PRINT 108
0222              IF(IEMISS.EQ.0) PRINT 109
0223              LENTRP=LEN
0224              PRINT 100,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
0225              GO TO 3
0226        25    STOP
0227        100   FORMAT(11I3,2F10.3)
0228        101   FORMAT (8F10.3)
0229        102   FORMAT (F6.1,2(F9.3,F5.1,F9.3,2F7.1))
0230        103   FORMAT(4(F6.2,2F7.5))
0231        105   FORMAT (15F5.2)
0232        106   FORMAT (3E9.2)
0233        107   FORMAT(12F6.3)
0234        108   FORMAT('1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE')
0235        109   FORMAT('1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE')
0236        110   FORMAT (/10X,38H EQUILAVENT SEA LEVEL ABSORBER AMOUNTS//21X110HWAT
                 1ER VAPOUR      CO2 ETC.        OZONE     NITROGEN (CONT)  H2O (CONT)
                 2    MOL  SCAT       AEROSOL  OZONE(UV-VIS)/24X,7HGM CM-2,10X,2HKM,1
                 30X,6HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM,13X,2HKM,10X,6HATM CM)
0237        111   FORMAT(//21X,64HNITRIC ACID         SO2            NO             NH3
                 1             NO2/)
0238        112   FORMAT (/10X,8H W(1-9)=3(E14.3)/)
0239        113   FORMAT(1H1,50X,'RADIANCE(WATTS/CM2-STER-XXX)')
0240        114   FORMAT (30X,'FR(CM-1)  WVL(MICRON)       PER CM-1    PER MICRON','
                 1  INTEGRAL           TRANS')
0241        115   FORMAT (1H1,/10X,23H  FREQ WAVELENGTH    H2O,5X4HCO2+,5X,5HOZONE
                 1N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL /11X,14H CM-1  MICRON
                 1S,7(4X5HTRANS),4X,5H ABS )
0242        116   FORMAT(30X,F8.1,F13.6,3E13.5,F13.6)
0243        118   FORMAT(10X,I6,9F9.4)
0244        119   FORMAT(' RADMIN ',F12.3,E12.5,/,' RADMAX ',F12.3,E12.5)
0245        120   FORMAT (' INTEGRATED ABSORPTION FROM',I5,' TO',I5,' CM-1 =',F10.2,
                 1',AVERAGE TRANSMITTANCE =',F6.4)
0246        121   FORMAT(' INTEGRATED RADIANCE =',E12.5,'WATT CM -2  SR')
0247        122   FORMAT (7F10.3)
0248        123   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1
                 14H CM-1 FOR DV =,F6.1,9H CM-1    (,F6.2,' - ',F5.2,' MICRONS )')
0249        124   FORMAT(10F8.4)
0250        125   FORMAT(10F8.4)
0251        126   FORMAT(10F8.3)
0252        127   FORMAT(10F8.4)
0253        128   FORMAT(/10X,10H W(11-15)=5(E14.3)/)
0254        129   FORMAT(//10X,23H  FREQ WAVELENGTH    SO2,6X2HNO,7X,3HNH3       NO2
                 1 INTEGRATED  TOTAL/11X,14H CM-1  MICRONS,4(4X5HTRANS),1X,10HABSORP
                 2TION,2X,5HTRANS)
0255        130   FORMAT(10X,I6,7F9.4)
0256        132   FORMAT(4F8.3)
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 0257               END
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```
0001            SUBROUTINE ABSORB(IXY,LENTOF,HZ,HMIX,W,TX,V1,V2,DV,ZLAM,SUMA,WLAY)
0002            COMMON /M01/ Z(34),P(7,34),T(7,34),FH(15,34),WH(7,34),M,ML,FE,CW,C
               1D,PI,WA(7,34)
0003            COMMON /M02/ IFIND,CA,IP,JSTOP
0004            COMMON /M03/ HZ1(34),HZ2(6),WC(7,34)
0005            COMMON /M04/ IHAZE,JP,IM,M1,M2,M3,ML,RO,TROUND
0006            COMMON /M09/ RADMAX,RADMIN,VPMAX,VPMIN
0007            COMMON /M014/ PPMSO2,PPMNO,PPMNH3,PPMNO2
0008            COMMON /EM1/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE
0009            COMMON /EM3/ H1,H2,R21,MODEL
0010            DIMENSION AHAZE(34),ASTOR(34),AHZ2(20),WLAY(34,15),VH(15),W(15),E(
               115),TX(15),HMIX(34),HZ(2)
          C*****************************************************************
          C
          C     THIS SUBROUTINE CALCULATES THE EQUIVALENT ABSORBER AMOUNT FOR EACH
          C     GAS AND FOR ANY PATH GEOMETRY
          C
          C     FH(1-15) ARE ABSORBER AMOUNTS PER KM AT LEVEL I, W(1-15) ARE
          C     EQUIVALENT ABSORBER AMOUNTS AT A GIVEN ALTITUDE.
          C
          C*****************************************************************
0011            F(X)=EXP(18.9766-14.9595*A-2.43882*A*A)*A
0012            IF(IXY.EQ.3) GO TO 1
0013            IF(M.EQ.7.AND.IM.NE.0)GO TO 3
0014            IF(IXY.GT.3) GO TO 13
0015            IF (MODEL.EQ.0) GO TO 3
0016      1     READ 100, H1,H2,ANGLE,RANGE,BETA,VIS
0017            PRINT 101, H1,H2,ANGLE,RANGE,BETA,VIS
          C**NOW CONSTRUCT THE PARAMETER FOR CALCULATING CONSTANT PRESSURE PATH ON
0018            X1=RE+H1
0019            IF (ITYPE.EQ.3) GO TO 8
0020            IF (ITYPE.EQ.1) GO TO 13
0021            X2=RE+H2
0022            IF (RANGE.EQ.0.) GO TO 10
0023            PRINT 102, H1,H2,ANGLE,RANGE,BETA,VIS
0024            IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 2
0025            ANGLE=ARCOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA
0026            GO TO 12
0027      2     X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)
0028            H2=X2-RE
0029            GO TO 12
0030      3     CONTINUE
0031            IF(ML.LE.0)ML=1
0032            DO 7 K=1,ML
0033            AHAZE(K)=0.0
0034            IF(M.EQ.0)READ 103,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE
0035            IF(M.EQ.0)PRINT 104,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE
0036            IF(M.GT.0)READ 103,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WC(7,K),AHAZE(K)
0037            IF(M.EQ.0)Z(K)=H1
0038            J=IFIX(Z(K)+1.0E-6)+1.
0039            IF(Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.
0040            IF(Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.
0041            IF(Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.
0042            IF(J.GT.33)J=33
0043            FAC=Z(K)-FLOAT(J-1)
0044            IF(J.LT.26) GO TO 4
0045            FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.
0046            IF(J.GE.31) FAC=(Z(K)-50.0)/20.
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                IF(J.GE.32) FAC=(Z(K)-70.0)/30.
                IF(FAC.GT.1.0) FAC=1.0
          4     L=J+1
                T(7,K)=TMP+273.15
                IF(M1.GT.0)T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC
                TT=273.15/T(7,K)
                IF(RH.LE.0.0) TT=273.15/(273.15+DP)
                IF(WH(7,K).LE.0.0) WH(7,K)=F(TT)
                IF(M2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC
                IF(RH.GT.0.0) WH(7,K)=0.01*RH*WH(7,K)
                IF(M3.GT.0)WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC
                HSTOR(K)=0.
                IF(HMIX(J).LE.0.) GO TO 5
                HSTOR(K)=HMIX(J)*(HMIX(L)/HMIX(J))**FAC
          5     CONTINUE
                IF(Z(K).GE.5.0)GO TO 6
                IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ2(J)*(HZ2(L)/HZ2(J))**FAC
          6     IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ1(J)*(HZ1(L)/HZ1(J))**FAC
                IF(MODEL.EQ.0)GO TO 13
                IF(K.EQ.1)PRINT 105
                PRINT 103,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K)
          7     CONTINUE
                IM=0
                ML=ML
                M1=0
                M2=0
                M3=0
          C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
          C     MODEL ATMOSPHERES
                IF (IXY.GE.3) GO TO 13
                GO TO 1
          8     IF (RANGE.GT.0.0) GO TO 9
                IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1
                GO TO 13
          9     ITYPE=2
                BETA=ARCOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA
         10     IF (BETA.EQ.0.) GO TO 11
                IFIND=1
                BET=CA*BETA
                X2=RE+H2
                ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA
                RANGE=X2*SIN(BET)/SIN(ANGLE*CA)
                BET=BETA
                GO TO 13
         11     RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2
                IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))
         12     IF (ANGLE.NE.0..OR.ANGLE.NE.180.)BET=ARSIN(RANGE*SIN(ANGLE*CA)/X2)
                IF (ANGLE.LT.0.) ANGLE=ANGLE+PI
                IF (RANGE.LT.0.0) RANGE=-RANGE
                BET=BET/CA
                PRINT 102, H1,H2,ANGLE,RANGE,BET,VIS
         13     CONTINUE
                DO 14 I=1,34
                DO 14 J=1,KMAX
         14     WLAY(I,J)=0.
                SUMA=0.
                IF(IXY.LE.2) READ 100,V1,V2,DV
                IF(IXY.LE.2)PRINT 100,V1,V2,DV
```

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      IF (ITYPE.EQ.1) PRINT 106, H1,RANGE
      IF (ITYPE.EQ.2) PRINT 107, H1,H2,ANGLE
      IF (ITYPE.EQ.3) PRINT 108, H1,ANGLE
      IF (MODEL.EQ.0) M=7
      IF(VIS.GT.0.0) PRINT 109,VIS
      IF(VIS.LT.2.0.AND.VIS.GT.0.0) PRINT 110
      IF (M.EQ.1) PRINT 111, M
      IF (M.EQ.2) PRINT 112, M
      IF (M.EQ.3) PRINT 113, M
      IF (M.EQ.4) PRINT 114, M
      IF (M.EQ.5) PRINT 115, M
      IF (M.EQ.6) PRINT 116, M
      IF (IHAZE.EQ.0.) PRINT 117
      IF(VIS.LE.0.0.AND.IHAZE.GT.0) PRINT 118,IHAZE,HZ(IHAZE)
      AVW=10000./V1
      ALAM=10000./V2
      RADMIN=1.0E+74
      RADMAX=0.
      VRMIN=0.
      VRMAX=0.
      PRINT 119, V1,V2,DV,ALAM,AVW
      AVW=0.5E-4*(V1+V2)
      AVW=AVW*AVW
      CO=77.46+.459*AVW
      CW=43.487-0.3473*AVW
      IF (IFIND.EQ.1) GO TO 19
   15 IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LEN,HL)
      IFIND=0
      IF (JP.EQ.0) PRINT 120
      IF (ITYPE.EQ.1) GO TO 19
      DO 16 K=1,KMAX
      VH(K)=0.0
   16 CONTINUE
      BETA=0.0
      SR=0.0
      IP=0
C**** NOW DEFINE CONSTANT PRESSURE PATH QUANTITIES  EH(I-8)
      Y=CA*ANGLE
      SPHI=SIN(Y)
      P1=(RE+H1)*SPHI
      IF (H1.GT.Z(NL)) GO TO 17
      GO TO 19
   17 X=(RE+Z(NL))/(RE+H1)
      IF (SPHI.GT.X) GO TO 18
      H1=Z(NL)
      J1=NL
      SPHI=SPHI/X
      ANGLE=180.0-ARSIN(SPHI)/CA
      P1=(RE+H1)*SPHI
      GO TO 19
   18 HMIN=P1-RE
      PRINT 122, HMIN
      GO TO 59
   19 DO 22 I=1,NL
      PS=P(M,I)/1013.0
      TS=273.15/T(M,I)
      IF(H1.GT.0.AND.M.LT.7)TS=273.15/T(M1,I)
      X=PS*TS
```

```
      PT=PS*SQRT(TS)
      D=0.1*WH(M,I)
      IF(M2.GT.0.AND.M.LT.7) D=0.1*WH(M2,I)
      EH(1,I)=D*PT**0.9
      EH(2,I)=X*PT**0.75
      EH(4,I)=0.3*PT*X
      PPW=4.56E-5*D*273.15/TS
      TS1=(296.0/273.15)*TS
      EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D*(PS-PPW)
      EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))
      EH(6,I)=X
      HAZE=HZ1(I)
      IF(M.EQ.7) HAZE=AHAZE(I)
      IF(Z(I).GE.5.0) GO TO 20
       IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)
      IF(IHAZE.EQ.2.AND.M.EQ.7)HAZE=AHZ2(I)
      IF(VIS.LE.0.0) GO TO 20
      IF(M.NE.7)HAZE= 6.389*((HZ2(I)-HZ1(I))/VIS+HZ1(I)/5.0-HZ2(I)/23.0)
      IF (M.NE.7) GO TO 20
      HAZE=6.339*((AHZ2(I)-AHAZE(I))/VIS+AHAZE(I)/5.0-AHZ2(I)/23.0)
20    IF(HAZE.LT.0.0) HAZE=0.0
      EH(7,I)=HAZE/HZ1(I)
      IF(MODEL.EQ.7) EH(7,I)=HAZE/AHAZE(1)
      EH(8,I)=46.6667*WO(M,I)
      IF(M3.GT.0.AND.M.LT.7) EH(8,I)=46.667*WO(M3,I)
      EH(3,I)=EH(8,I)*PT**0.4
C EH(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM
      EH(11,I)=PS*TS*HMIX(I)*1.0E-04
      IF (MODEL.EQ.0.OR.MODEL.EQ.7) EH(11,I)=PS*TS*HSTOR(I)*1.0 E-04
C*****EH(12,I) = SO2 ABSORBER AMOUNT (ATM-CM)/KM
      EH(12,I)=0.772E-04*PPMSO2*WA(M,I)*PS**0.07122*TS**0.06159
      EH(13,I)=0.772E-04*PPMNO*WA(M,I)*PS**0.90099*TS**1.01192
      EH(14,I)=0.772E-04*PPMNH3*WA(M,I)*PS**0.52125*TS**(-0.60436)
      EH(15,I)=0.772E-04*PPMNO2*WA(M,I)*PS**0.13066*TS**0.20911
      EH(9,I)=1.0
      REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)
      IF (I.EQ.NL) GO TO 21
      IF (MODEL.EQ.0.AND.I.GE.1) GO TO 36
      T2=T(M,I+1)
      W2=WH(M,I+1)
      IF(M1.GT.0)T2=T(M1,I+1)
      IF(M2.GT.0)W2=WH(M2,I+1)
      PPW=4.56E-6*W2*T2
      EH(9,I)=0.5*(REF+1.0E-6*(CO*P(M,I+1)/T2-PPW*CW))
21    IF (I.EQ.NL) EH(9,I)=0.
      IF (H1.GE.Z(I)) J1=I
      IF(IFIND.EQ.0.OR.JP.EQ.0) PRINT 123, I,Z(I),(EH(K,I),K=1,12)
      EH(9,I)=EH(9,I)+1.0
22    CONTINUE
23    IF (IFIND.EQ.1) GO TO 15
      IP=1
      IK=0
      X1=H1
      CALL POINT (H1,YN,N,NP1,TX,IP)
      J1=N
      TX1=TX(9)
      DO 24 K=1,KMAX
24    E(K)=TX(K)
```

```
C**ITYPE=1 MEANS HORIZONTAL PATH ******************************************
      IF (ITYPE.EQ.1) GO TO 36
      IF (ITYPE.EQ.3) H2=Z(NL)
C** ANGLE GREATER THAN 90 DEGREES MEANS DOWNWARD TRAJECTORY ************
      IF (ANGLE.GT.90.0) GO TO 34
C** IF THE PATH IS NOT HORIZONTAL OR DOWNWARD THEN IT IS UPWARD TRAJECTORY
 25   IF (ANGLE.GT.90.0.AND.NPI.GT.0) J1=J1+1
      J2=NL
      IF (ITYPE.EQ.3) GO TO 26
      CALL POINT (H2,YN,A,NP,TX,IP)
      J2=N
      IF (NP.GT.0) J2=J2-1
 26   DO 27 K=1,KMAX
      IF(K.EQ.9) GO TO 27
      FH(K,J1)=F(K)
      IF (ITYPE.EQ.3) GO TO 27
      FH(K,J2+1)=TX(K)
 27   CONTINUE
      IF (J1.EQ.J2) TX1=TX1+YN-FH(9,J1)
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)
      IF (IP.EQ.0) PRINT 124
      DO 28 K=1,KMAX
 28   W(K)=0.
      DO 35 I=J1,J2
      X1=Z(I)
      X2=Z(I+1)
      IF (I.EQ.J1) X1=H1
      IF (I.EQ.J2) X2=H2
      DZ=X2-X1
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)
      DS=DZ
C***** UPWARD TRAJECTORY
      RX=(RE+X1)/(RE+X2)
      THETA=ARSIN(SPHI)/CA
      PHI=ARSIN(SPHI*RX)/CA
      BET=THETA-PHI
      SALP=RX*SPHI
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BETA*CA)/SPHI
      BETA=BETA+BET
      PSI=BETA+PHI-ANGLE
      PHI=180.-PHI
      SS=SS+DS
      JEXTRA=0
      DO 34 K=1,KMAX
      FV=DS*FH(K,I)
      IF (I.EQ.NL) GO TO 29
      IF (FH(K,I).EQ.0.0.OR.FH(K,I+1).EQ.0.0) GO TO 30
      IF (FH(K,I).EQ.FH(K,I+1)) GO TO 31
      FV=DS*(FH(K,I)-FH(K,I+1))/ALOG(FH(K,I)/FH(K,I+1))
      GO TO 31
 29   IF (FH(K,I).EQ.0.0) GO TO 30
      IF (FH(K,I-1).EQ.0.0) GO TO 30
      IF (FH(K,I).EQ.FH(K,I-1)) GO TO 31
      FV=FV/ALOG(FH(K,I-1)/FH(K,I))
      GO TO 31
 30   FV=0.
 31   VH(K)=VH(K)+FV
      IF(I.EQ.JSTOP) GO TO 33
```

```
 32    WLAY(I,K)=EV+W(K)
       W(K)=0.
       GO TO 34
 33    W(K)=EV
       IF(J1.NE.J2) GO TO 34
       WLAY(J2+1,K)=W(K)
       W(K)=0.
       JEXTRA=1
 34    CONTINUE
       IF (JP.EQ.0) PRINT 125, I,X1,(VH(L),L=1,8),PSI,PHI,BETA,THETA,S-
       IF (I.GE.NL) GO TO 35
       IF (I+1.EQ.J2) EH(9,I+1)=YN
       IF (I.EQ.J1) EH(9,I)=TX1
       RX=EH(9,I+1)/EH(9,I)
       SPHI=SPHI*RX/EN
       IF (SALP.GE.EN) SPHI=SALP
 35    CONTINUE
       GO TO 58
C****  HORIZONTAL PATH
 36    DO 37 K=1,KMAX
       W(K)=RANGE*EH(K,I)
       IF (MODEL.GT.0) W(K)=RANGE*TX(K)
       VH(K)=W(K)
 37    CONTINUE
       GO TO 60
 38    CONTINUE
C****  DOWNWARD TRAJECTORY
       K2=0
       IF (NP1.EQ.1) J1=J1-1
       J2=J1+1
       J=J1+1
       YN1=YN
       IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 40
       IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 40
       CALL POINT (H2,YN,N,NP2,TX,IP)
       DO 39 K=1,KMAX
 39    W(K)=TX(K)
       TX2=TX(9)
       YN2=YN
       IF (H2.LT.H1) H=H2
       J2=N
       IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)
       IF (H2.GT.H1) TX1=TX2
       IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2
 40    Z=-(RE+H1)*SPHI+YN1
       IF (H2.GE.H1) YN2=YN1
       DO 41 I=1,J1
       HMIN=A0/EH(9,I)-RE
       IF (I.EQ.J1) HMIN=A0/YN1-RE
       JMIN=I
       IF (HMIN.LE.Z(I+1)) GO TO 42
 41    CONTINUE
 42    X=HMIN
       IF (HMIN.LE.0) GO TO 44
       CALL POINT (X,YN,N,NP,TX,IP)
       JMIN=N
       TX3=TX(9)
       IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)
```

```
      IF(TX3.LT.0.0)TX3=TX(9)
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 43
      HMIN=AJ/TX3-RE
      IF (ABS(X-HMIN).GT.0.0001) GO TO 42
43    IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3
      IF (H2.GE.H1) TX2=TX3
      IF (H2.GE.H1) J2=N
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
      PRINT 126, HMIN
      IF(H2.LT.HMIN)J2=N
      IF (H2.LT.HMIN) PRINT 127, HMIN
      GO TO 45
44    PRINT 126,HMIN
      IF (H2.LT.H1) GO TO 45
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 128
      ITYPE=2
      TX2=EH(9,1)
      JMIN=0
      J2=1
      H2=0.0
      H=0.0
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)
45    IF(JP.EQ.0) PRINT 124
      JSTOR=J-1
      DO 51 I=1,NL
      J=J-1
      REF=EH(9,J)
      IF (I.EQ.1) REF=YN1
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2
      IF (I.NE.1) X1=Z(J+1)
      X2=Z(J)
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN
      HM=(RE+X1)*SPHI-RE
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM
      RX=(RE+X1)/(RE+X2)
      DS=X1-X2
      ALP=90.0
      THET=ARSIN(SPHI)/CA
      SALP=RX*SPHI
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ARSIN(SALP)/CA
      BET=ALP-THET
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
      THETA=180.0-THET
      BETA=BETA+BET
      PSI=BETA-ALP-ANGLE+180.0
      SR=SR+DS
      DO 50 K=1,KMAX
      AJ=EH(K,J)
      BJ=EH(K,J+1)
      IF (J.EQ.J1) BJ=E(K)
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)
      IF (K2.EQ.0) GO TO 46
      IF (J.EQ.J2) BJ=W(K)
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      IF (J.EQ.JMIN) AJ=TX(K)
   46 IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 48
      IF (AJ.EQ.BJ) GO TO 47
      FV=DS*(AJ-BJ)/ALOG(AJ/BJ)
      GO TO 49
   47 FV=DS*AJ
      GO TO 49
   48 FV=0.0
   49 VH(K)=VH(K)+FV
   50 WLAY(J,K)=FV
      IF (JP.EQ.0) PRINT 125, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 55
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 54
      IF (J.NE.1) RN=REF/EH(9,J-1)
      IF (J.EQ.J2+1) RN=REF/TX2
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3
      IF (SALP.GE.RN) RN=1.0
      SPHI=SALP*RN
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 52
   51 CONTINUE
   52 IF (HMIN.LE.0) GO TO 58
      IF (LEN.EQ.0) PRINT 129
      IF (LEN.EQ.0) GO TO 58
      IF (LEN.EQ.1) PRINT 130
      K2=1
      X1=X2
      IF (ABS(X1-HMIN).LE.0.001) GO TO 58
      H=HMIN
      J=J2+1
      IF (NP2.EQ.1) J=J-1
      B=BETA
      PH=180.0-ARSIN(SPHI)/CA
      TS=SR
      PS=PSI
      DO 53 K=1,KMAX
   53 E(K)=VH(K)
      GO TO 45
   54 BETA=2.*BETA-B
      PSI=2.*PSI-PS
      SR=2.*SR-TS
C     LONG PATH  TAKEN
      PHI=PH
      DO 55 K=1,KMAX
   55 VH(K)=2.*VH(K)-E(K)
      GO TO 58
   56 DO 57 K=1,KMAX
   57 VH(K)=2.0*VH(K)
      BETA=2.0*BETA
      SR=2.0*SR
      IF (H2.EQ.H1) GO TO 58
      RN=TX1/YN1
      SPHI=SIN(ANGLE*CA)
      IF (SPHI.LT.RN) SPHI=SPHI/RN
      GO TO 25
   58 CONTINUE
      IF(ANGLE.GT.90.0) PRINT 100,HM
      DO 59 K=1,KMAX
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0439           W(K)=VH(K)
0440      59   CONTINUE
0441      50   RETURN
0442     100   FORMAT (7F10.3)
0443     101   FORMAT (10X,7F10.3)
0444     102   FORMAT (10X,' H1=',F7.3,'KM,H2=',F7.3,'KM,ANGLE=',F6.4,'DEG, RANG
              1E =',F7.2,'KM,BETA=',F8.5,',VIS=',F6.1)
0445     103   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)
0446     104   FORMAT(10X,'INPUT METEOROLOGICAL DATA:'/10X,'Z=',F7.2,' KM, P=',F7
              1.2,' MB,T=',F5.1,' C, DEW PT.TEMP',F5.1,' C, REL HUMIDITY=',F5.1,
              2' %, H2O DENSITY=',1PE9.2,' GM M-3'/10X,' OZONE DENSITY=',E9.2,' G
              3M-3, VISUAL RANGE=',0PF6.1,' KM,RANGE=',F10.3,' KM ' )
0447     105   FORMAT(' MODEL ATMOSPHERE NO. ',I1,/ 4X,'Z (KM)',3X,'P (MB)',4X,
              1 'T (C) DEW PT 8PH  H2O(GM,M-3) O3(GM,M-3) NO. DEN.')
0448     106   FORMAT (//10X,29H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,
              1F7.3,3H KM)
0449     107   FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1
              1=,F7.3,8H KM H2 =,F7.3,19H KM,ZENITH ANGLE =,F7.3,8H DEGREES)
0450     108   FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H
              1KM, ZENITH ANGLE =,F7.3,8H DEGREES)
0451     109   FORMAT (/25X'HAZE MODEL  =',F5.1,' KM VISUAL RANGE AT SEA LEVEL')
0452     110   FORMAT(' FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RA
              1NGE',/,' IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN
              2BY THE TRANSMITTANCE AT 0.55 MICRONS')
0453     111   FORMAT (/20X,19H MODEL ATMOSPHERE ,I1,11H = TROPICAL)
0454     112   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)
0455     113   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)
0456     114   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )
0457     115   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )
0458     116   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )
0459     117   FORMAT (/20X,'AEROSOL SCATTERING NOT COMPUTED,IHAZE=0')
0460     118   FORMAT (/20X,18H        HAZE MODEL ,I1,3H = ,A5,13H VISUAL RANGE)
0461     119   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1
              14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,' - ',F5.2,' MICRONS )')
0462     120   FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)
0463     121   FORMAT (' STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED:H1=
              1 ',F10.3,'ANGLE =',F10.6)
0464     122   FORMAT (' TRAJECTORY MISSES EARTHS ATMOSPHERE, CLOSEST DISTANCE OF
              1 APPROACH IS',F10.2,1X,/,1X,'END OF CALCULATION')
0465     123   FORMAT (3X,I3,F6.1,12(F10.3))
0466     124   FORMAT(1H1,///10X,'  VERTICAL PROFILES  ',45X,'PSI',6X,'PHI',6X,'B
              1ETA',4X,'THETA    RANGE')
0467     125   FORMAT(I3,F6.1,8E10.3,4F9.4,F6.1)
0468     126   FORMAT (' HMIN = ',F10.3)
0469     127   FORMAT (' H2 WAS SET LESS [illegible]
              1  HMIN I.E. H2 = ',F10.3)
0470     128   FORMAT (' PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 =
              1 0.0 KM')
0471     129   FORMAT (' CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN.
              1 FOR LONGER PATH SET LEN=1.')
0472     130   FORMAT (' CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.
              1 FOR SHORT PATH SET LEN = 0 ')
0473           END
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      SUBROUTINE POINT (X,YN,N,NP,TX,IP)
      COMMON /MOD/ Z(34),P(7,34),T(7,34),FH(15,34),WH(7,34),M,NL,FE,CW,C
     1O,PI,WA(7,34)
      COMMON /EMI/ IEMISS,KMAX
      DIMENSION TX(15)
C*********************************************************************
C      SUBROUTINE POINT COMPUTES THE MEAN REFRACTIVE INDEX ABOVE AND BELOW
C      A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
C      EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
C
C*********************************************************************
C
C       X IS THE HEIGHT IN QUESTION
C       TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
C       N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
C       NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0
C       TX(1-8) ARE ABSORBER AMOUNTS PER KM AT HEIGHT X
C*********************************************************************
      N=NL
      NP=0
      IF (X.LT.0.0) X=0.
      IF (X.GT.Z(NL)) GO TO 4
      DO 1 I=1,NL
      N=I
      IF (X-Z(I)) 2,4,1
    1 CONTINUE
    2 J2=N
      N=N-1
      FAC=(X-Z(N))/(Z(J2)-Z(N))
      PX1=P(M,N)*(P(M,J2)/P(M,N))**FAC
      TX1=T(M,N)*(T(M,J2)/T(M,N))**FAC
      WX1=WH(M,N)*(WH(M,J2)/WH(M,N))**FAC
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*WH(M,J2)*T(M,J2)*CW
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*WH(M,N)*T(M,N)*CW
      TX(9)=0.5E-6*(TX(2)+TX(3))
      YN=0.5E-6*(TX(1)+TX(3))
      IF (IP.EQ.0) GO TO 9
      DO 3 K=1,KMAX
      IF(K.EQ.9) GO TO 3
      TX(K)=0.0
      IF (FH(K,N).EQ.0.0) GO TO 3
      IF (FH(K,N).GT.1000.0) GO TO 3
      TX(K)=FH(K,N)*(FH(K,J2)/FH(K,N))**FAC
    3 CONTINUE
      GO TO 9
    4 NP=1
      IF (IP.EQ.0) GO TO 6
      DO 5 K=1,KMAX
    5 TX(K)=FH(K,N)
    6 TX(9)=FH(9,N)-1.
      YN=0.0
C*****  CARDS B 24 AND 50 THROUGH 55 ARE NO LONGER REQUIRED
      IF (N.GT.1) YN=FH(9,N-1)-1.0
    9 CONTINUE
      IF (IP.EQ.1) PRINT 100, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)
      TX(9)=TX(9)+1.
      YN=YN+1.
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FORTRAN IV G LEVEL  21                  POINT            DATE = 79218         16/22/49            PAGE 0002
 0044                RETURN
 0045         100    FORMAT (/,' FR  M F 1IT: HEIGHT=',F13.4,' KM,N=',I4,',MP=',I,',REF
                    1. INDEX ABOVE & BELOW X=',' I1.4,',IP=',I3,/,12X,'EQUIV. ABS NUMBER
                    2AM UNTS PER KM AT X=',4F10.3)
 0046                END
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FORTRAN IV G LEVEL  21                 PATH               DATE = 79218        16/22/49            PAGE 0001

0001              SUBROUTINE PATH(WLAY,WPATH,TBBY)
0002              COMMON /MOD1/ Z(34),P(7,34),T(7,34),CH(15,34),WH(7,34),M,NL,FE,CW,C
                 1C,PI,WA(7,34)
0003              DIMENSION WLAY(34,15),TBBY(68),WPATH(68,15)
0004              COMMON /EM1/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE
0005              COMMON /EM2/ IL,IKMAX  ,LENTOR,NLL,W(15),F(15)
0006              COMMON /EM3/ H1,H2,NP1,MODEL
0007              IF (ITYPE.EQ.1) GO TO 10
0008              IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1
0009              IF (H2.GT.H1.AND.ANGLE.GT.90..AND.NP1.EQ.1) J1=J1-1
0010              IF (JEXTRA.EQ.1) J2=J2+1
0011              IF((ITYPE.EQ.2).AND.(H1.GT.H2).AND.(LENTOR.EQ.1)) J2=J2-1
0012              IF (ITYPE.EQ.3) J2=NL
0013              PRINT 100, J1,J2
0014              PRINT 101
0015              DO 1 IK=1,68
0016              TBBY(IK)=0.
0017              DO 1 K=1,KMAX
0018              WPATH(IK,K)=0.
0019        1     CONTINUE
0020              LEN=0
0021              NLL=NL-1
0022              IL=J1+1
0023              IJ=IL+NLL
0024              DO 2 K=1,KMAX
0025              F(K)=0.
0026        2     CONTINUE
0027              IF (ANGLE.GT.90.0) GO TO 3
0028              LEN=1
0029              IL=J1-1
0030              HMIN=1.0E-6
0031              IJ=NLL
0032        3     CONTINUE
0033              DO 8 IK=1,68
0034              IF (LEN.EQ.0) IL=IL-1
0035              IF (LEN.EQ.1) IL=IL+1
0036              IJ=IJ-1
0037              IF (IL.EQ.0) GO TO 8
0038              DO 4 K=1,KMAX
0039              W(K)=F(K)+WLAY(IL,K)
0040              WPATH(IK,K)=W(K)
0041        4     CONTINUE
0042              IF (IL.LE.0.OR.IL.GE.NL) GO TO 5
0043              TBAR=(T(M,IL)+T(M,IL+1))*0.5
           C      JEXTRA IS 1 ONLY WHEN PROGRAM NEVER LEAVES ONE LAYER
0044              IF (JEXTRA.EQ.1) TBAR=(T(M,J1)+T(M,J1+1))*0.5
0045        5     CONTINUE
0046              TBBY(IK)=TBAR
0047              DO 6 K=1,KMAX
0048              F(K)=W(K)
0049        6     CONTINUE
0050              IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 9
0051              IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 7
0052              IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 9
0053              IF(ITYPE.EQ.2.AND.LENTOR.EQ.0.AND.IL.EQ.J2) GO TO 9
0054              IF (IL.EQ.JMIN.AND.HMIN.GT.0) LEN=1
0055              IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 9
0056              IF (LEN.EQ.0) GO TO 7
```

```
0057              IF (IL.EQ.IMIN.AND.IJ.EQ.IL+NLL) IL=IL-1
0058              IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 3
0059       7      CONTINUE
0060              PRINT102,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),WPATH(IK
                 1,12),TRAY(IK)
0061              CONTINUE
0062              IKMAX=68
0063              LEN=LENSTOR
0064              RETURN
0065              CONTINUE
0066              PRINT102,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),WPATH(IK
                 1,12),TRAY(IK)
0067              IKMAX=IK
0068              LEN=LENSTOR
0069              RETURN
0070      10      DO 11 K=1,KMAX
0071              WPATH(1,K)=W(K)
0072      11      CONTINUE
0073              IF (MODEL.EQ.0) J1=1
0074              J2=J1
0075              TRAY(1)=T(M,J1)
0076              IKMAX=1
0077              PRINT 100, J1,J2
0078              PRINT 101
0079              IK=1
0080              PRINT102,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),WPATH(IK
                 1,12),TRAY(IK)
0081              HMIN=1.0E-6
0082              RETURN
0083     100      FORMAT(9I3)
0084     101      FORMAT (//,20X,' CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC P
                 1ATH',//
                 210X,'H2O',5X,'CO2+',8X,'O3',9X,'N2',3X,'H2O C',6X,'MOL S',7X,'AER
                 3',5X,'O3 UV',7X,'H2O C',7X,'HNO3',6X,'SO2',6X,'TAVE')
0085     102      FORMAT(I5,10E11.3,F9.3,F8.3)
0086              END
```

```
FORTRAN IV G LEVEL  21                 ANGL              DATE = 79218         16/22/49              PAGE 0001

0001                SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,ML)
0002                COMMON /MOI/ Z(34),P(7,34),T(7,34),EH(15,34),WH(7,34),M,NL,RE,LW,C
                   1O,PI,WA(7,34)
0003                COMMON /EMI/ IEMISS,KMAX
0004                DIMENSION TX(15)
              C***********************************************************************
              C
              C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)
              C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
              C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
              C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
              C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
              C     ATMOSPHERE.
              C
              C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
              C***********************************************************************
0005                IP=99
0006                CA=PI/180.
0007                X1=RE+H1
0008                X2=RE+H2
0009                LEN=0.
0010                IT=0
0011                B1=B1*CA
0012                IF(B1.EQ.0.0) B1=ARCOS(X2/X1)
0013                TANG=X2*SIN(B1)/(X2*COS(B1)-X1)
0014                THET=ATAN(TANG)
0015                IF (THET.LT.0.0) THET=THET+PI
0016                SPHI=SIN(THET)
0017                ANG=THET/CA
              C     PRINT 404, B1,ANG,TANG
0018                TN=THET
0019                TN=TN-0.5*CA
0020          1     ANGLE=THET
0021                FBT=0.
0022                BETA=0.
0023                BET1=0
0024                BET2=0
0025                FBT1=0
0026                FBT2=0
0027                FBT3=0.0
0028                IF(B1.LE.0.0) GO TO 2
              C     PRINT 400, IT
0029                Y=2.*THET
0030                IF (Y-[illegible].LT.1.0E-8) GO TO 9
0031                IF (IP.EQ.100) GO TO 6
0032                XMIN=X2*COS(B1)-RE
0033                IF (XMIN-H1) 8,4,4
0034            2   HMIN=H2
0035                H2=H1
0036                H1=HMIN
0037          3     ANGLE=0.5*PI
0038                THET=ANGLE
0039                SPHI=1.0
0040                ANG=ANGLE/CA
              C     PRINT 404, B1,ANG,SPHI
0041          4     IP=100
0042                CALL POINT (H1,YN,N,NP,TX,IP)
0043                J1=N
```

```
0044             TX1=TX(9)
0045       5     CALL POINT (H2,YN,N,NP,TX,IP)
0046             IF (NP.EQ.1) N=N-1
0047             J2=N
0048             IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
0049       6     DO 7 J=J1,J2
0050             X1=RE+Z(J)
0051             X2=RE+Z(J+1)
0052             IF (J.EQ.J1) X1=RE+H1
0053             IF (J.EQ.J2) X2=RE+H2
0054             SALP=X1*SPHI/X2
0055             ALP=ARSIN(SALP)
0056             RN=EH(9,J+1)/EH(9,J)
0057             IF ((J+1).EQ.J2) RN=YN/EH(9,J)
0058             IF (J.EQ.J1) RN=EH(9,J+1)/TX1
0059             IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1
0060             BET=THET-ALP
0061             RS=-TAN(ALP)
0062             IF (J.NE.J1) RS=RS+TAN(THET)
0063             ERT=ERT+RA
0064             BETA=BETA+BET
0065             THI=THET/CA
0066             BE=BET/CA
0067             C=ALP/CA
           C     PRINT 402, J,Z(J),THET,ALP,BET,BETA,ERT,RS,THI,BE,C
0068             IF (X2.EQ.RE+H2) C=PI-ALP
0069             IF (SALP.GE.RN) RN=1.
0070             SPHI=SALP/RN
0071             THET=ARSIN(SPHI)
0072       7     CONTINUE
0073             IF(H1.LE.0.0) GO TO 29
0074             GO TO 26
0075       8     CONTINUE
0076             TANG=-TANG
0077             ANGLE=PI-ANGLE
0078             TN=ANGLE
0079             ANG=ANGLE/CA
           C     PRINT 404, H1,ANG,TANG
0080             IF (H1.LE.0.0) GO TO 3
0081       9     CONTINUE
0082             IP=1J1
0083             CALL POINT (H1,YN,N,NP1,TX,IP)
0084             TX1=TX(9)
0085             YN1=YN
0086             IF (NP1.EQ.1) N=N-1
0087             J2=NL
0088             IF (Z.EQ.7) J2=ML
0089             J1=N
0090             J=J1+1
0091             IF (H2.GE.H1) GO TO 13
0092             CALL POINT (H2,YN,N,NP,TX,IP)
0093             TX2=TX(9)
0094             YN2=YN
0095             J2=N
0096             IF (J1.EQ.J2) TX2=YN1+TX(9)-EH(9,J1)
0097      10     J=J-1
0098             X1=RE+Z(J+1)
0099             X2=RE+Z(J)
```

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FORTRAN IV G LEVEL  21               ANGL               DATE = 79218          16/22/49               PAGE 0003

0100                IF (J.EQ.J1) X1=RE+H1
0101                IF (J.EQ.J2) X2=RE+H2
0102                SALP=X1*SPHI/X2
0103                HMIN=X1*SPHI-RE
              C     PRINT 402, J,X1,Z(J),SPHI,SALP,HMIN,RE
0104                IF (SALP.LE.1.0) GO TO 11
0105                SALP=SPHI
0106                IF (HMIN.GT.H2) GO TO 13
0107          11    ALP=ARSIN(SALP)
0108                THET=ARSIN(SPHI)
0109                BET=ALP-THET
0110                BET1=BET1+BET
0111                FR=TAN(ALP)
0112                IF (J.NE.J1) FR=FR-TAN(THET)
0113                FRT1=FRT1+FR
0114                THI=THET/CA
0115                BE=BET/CA
0116                AL=ALP/CA
              C     PRINT 402, J,X2,THET,ALP,BET1,BET,BMIN,HMIN,FRT1,THI,BE,AL
0117                IF (X2.EQ.RE+H2) C=PI-ALP
0118                REF=EH(9,J)
0119                IF (J.EQ.J1) REF=YN1
0120                IF (J.EQ.J2) REF=TX2
0121                IF (J.EQ.1) GO TO 12
0122                RN=EH(9,J)/EH(9,J-1)
0123                IF (J.EQ.J1) RN=YN1/EH(9,J-1)
0124                IF(J.EQ.J2+1) RN=REF/TX2
0125                IF(J.EQ.J2) RN=REF/YN2
0126                IF (SALP.GE.RN) RN=1.
0127                SPHI=SALP*RN
0128                IF (Z(J).LE.H2) GO TO 12
0129                GO TO 10
0130          12    X1=X2
0131                IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 13
0132                GO TO 14
0133          13    J=J-1
0134                X1=RE+Z(J+1)
0135                IF (J.EQ.J1) X1=RE+H1
0136                IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2
0137          14    X2=RE+Z(J)
0138                HMIN=X1*SPHI-RE
0139                IF (HMIN.LE.0.0) GO TO 25
0140                IF (Z(J).LT.HMIN) GO TO 18
0141                REF=EH(9,J)
0142                IF (J.EQ.J2) REF=YN
0143                SALP=X1*SPHI/X2
0144                ALP=ARSIN(SALP)
0145                THET=ARSIN(SPHI)
0146                BET=ALP-THET
0147                FR=TAN(ALP)-TAN(THET)
0148                FRT2=FRT2+FR
0149                BET2=BET2+BET
0150                BMIN=BET1+BET2
0151                AL=ALP/CA
0152                THI=THET/CA
              C     PRINT 402, J,X2,THET,ALP,BET2,BET,BMIN,HMIN,FRT2,THI,BE,AL
0153                RN=REF/EH(9,J-1)
0154                IF (SALP.GE.RN) RN=1.0
```

```
      SPHI=SALP*RN
      GO TO 13
17    TX3=YN1+TX(9)-EH(9,J1)
      YN1=TX3
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      RN=1.0
      GO TO 19
18    CALL POINT (HMIN,YN,N,NP,TX,IF)
      IP=102
      TX3=TX(9)
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)
      IF (HMIN.GT.H2) TX3=TX(9)
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17
      RN=REF/TX3
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP*RN
      X=X1*SPHI-PE
      DIF=ABS(HMIN-X)
      HMIN=X
      IF (DIF-1.0E-5) 19,18,18
19    X2=RF+HMIN
C     PRINT 403, HMIN,DIF,RN
      THET=ARSIN(SPHI)
      IF(RN.EQ.1.0) FRT3=-TAN(THET)
      IF (RN.EQ.1) GO TO 20
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)
      FRT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))
20    BET=0.5*PI-THET
      BET2=BET2+BET
      BMIN=BET1+BET2
      IF (H2.GE.H1) GO TO 23
      BET=BET1+2.*BET2
      DB1=H1-BET1
      DB2=BET-B1
21    DB3=ABS(BMIN-B1)
      IF(DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 25
      IF(DB2.GT.DB3) GO TO 22
      IF(DB3.GT.DB1) GO TO 25
      BETA=BET
      FRT=FRT1+2.0*(FRT2+FRT3)
      LEN=1.
      GO TO 26
      BETA=BET +BET
      FRT=F T1+F T2+ RT3
      PRINT 401, J,BETA,FRT,FRT1,FRT2,FRT3,TX1,YN1
      GO TO 26
23    BETA=2.0*(BET1+BET2)
      LEN=1.
      FRT=2.0*(FRT1+FRT2+FRT3)
      PRINT 401, J,BETA,FRT,FRT1,FRT2,FRT3,TX1,YN1
      IF (H2.EQ.H1) GO TO 26
      IP=103
      IF (NPL.EQ.1) J1=J1+1
      SPHI=SIN(ANGLE)
      IF (Z(J1+1).LE.H2) GO TO 24
      RN=TX1/YN1
```

```
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ARSIN(SPHI)
      GO TO 5
 24   CALL POINT (H2,YN,N,NP,TX,IP)
      TX1=TX1+YN-FH(9,J1)
      RN=TX1/YN1
      J2=J1
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ARSIN(SPHI)
      GO TO 5
 25   BETA=BET1
      LEN=0.
      FRT=FRT1
 26   THET=ANGLE+(B1-BETA)/(1.+FRT/TANG)
      DBETA=BETA/CA
      B=BET1/CA
      TH1=THET/CA
      PRINT 404, BETA,DBETA,FRT,TH1,TANG
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.
      TH1=THET/CA
      PRINT 404, BET1,B,FRT,TH1
      TN1=TN/CA
      TM1=TM/CA
      PRINT 405, TN,TM,TN1,TM1
      SPHI=SIN(THET)
      TANG=TAN(THET)
      IT=IT+1
      DBE=ABS(B1-BETA)
      DTH=ABS(ANGLE-THET)
      IF (IT.EQ.10)  THET=0.5*(ANGLE+THET)
      IF (IT.EQ.10) GO TO 28
      IF (DBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 1
 28   ANGLE=THET/CA
      PRINT 406, ANGLE,IT
      RETURN
   29 H1=H2
      ANGLE=0/CA
      PRINT 406, ANGLE,IT
      RETURN
C
 400  FORMAT (//' ITTERATION NUMBER ',I3,//)
 401  FORMAT (I6,F16.7,8F13.4)
 402  FORMAT (I4,F10.4,6F13.4,4F10.4/)
 403  FORMAT(' HMIN=',F14.6,'  DIF=',F14.6,'  PR=',F10.4)
 404  FORMAT (' TOTAL BETA = ',E14.6,F15.6,',FRT = ',E14.6,' THET =',F10
     1.6,'TANG=',F10.6)
 405  FORMAT (5F12.6)
 406  FORMAT (8X,/1H','ZENITH ANGLE =',F7.3,' DEGREES :  RECOMPUTED
     1 FROM SUBROUTINE ANGL (ITTERATION',I3,')')
      END
```

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FORTRAN IV G LEVEL  21                FREQSL            DATE = 79218          16/22/49                PAGE 0001

0001                SUBROUTINE FREQSL(I,IV,W,IHAZE,TX,ALAM)
0002                COMMON /MO5/ C1(2580),C2(1575),C3(540),C4(133),C5(15),C8(102),C11(
                   144),C12(115),C13(43),C14(109),C15(85)
0003                COMMON /MO6/ VX(45),C7(45),C7A(45)
0004                COMMON /MO7/ TR(67),FW(67),FC(67)
0005                COMMON /MO8/ SUM4,SUM5,SUM6,SUM7,SUM8,SUM11
0006                COMMON /MO10/ FS(9),S1(9),S2(9)
0007                COMMON /MO11/ FN3(9),FN1(9),FN2(9)
0008                COMMON /MO12/ FNH3(9),FH1(9),FH2(9)
0009                COMMON /MO13/ FNQ2(9),Q1(9),Q2(9)
0010                DIMENSION W(15),TX(15)
              C*********************************************************************
              C
              C     THIS SUBROUTINE SELECTS THE ATTENUATOR EFFECTIVE AT THE FREQUENCY
              C     INPUT FROM 13 MODEL SUBROUTINE.
              C
              C*********************************************************************
0011                IF (I.GE.01.AND.I.LE.18) GO TO 4
0012                IF (I.GE.19.AND.I.LE.30) GO TO 3
0013                IF (I.GE.31.AND.I.LE.45) GO TO 2
0014                IF (I.GE.46.AND.I.LE.54) GO TO 1
0015                IF (I.GE.55.AND.I.LE.60) GO TO 6
0016                IF (I.GE.61.AND.I.LE.64) GO TO 8
0017                IF ((I.GE.65.AND.I.LE.68).OR.(I.GE.499.AND.I.LE.510)) GO TO 9
0018                IF (I.GE.69.AND.I.LE.100) GO TO 10
0019                IF (I.GE.101.AND.I.LE.107) GO TO 11
0020                IF (I.GE.108.AND.I.LE.141) GO TO 12
0021                IF (I.GE.142.AND.I.LE.177) GO TO 15
0022                IF ((I.GE.178.AND.I.LE.181).OR.(I.GE.193.AND.I.LE.212)) GO TO 16
0023                IF ((I.GE.182.AND.I.LE.192).OR.(I.GE.213.AND.I.LE.238).OR.(I.GE.26
                   16.AND.I.LE.277)) GO TO 13
0024                IF (I.GE.239.AND.I.LE.265) GO TO 17
0025                IF ((I.GE.278.AND.I.LE.282).OR.(I.GE.326.AND.I.LE.346).OR.(I.GE.48
                   10.AND.I.LE.498).OR.(I.GE.511.AND.I.LE.531)) GO TO 14
0026                IF (I.GE.283.AND.I.LE.325) GO TO 18
0027                IF ((I.GE.347.AND.I.LE.420).OR.(I.GE.439.AND.I.LE.479)) GO TO 19
0028                IF (I.GE.421.AND.I.LE.438) GO TO 20
0029                IF (I.GE.531.AND.I.LE.595) GO TO 21
0030                IF (I.GE.596.AND.I.LE.1545) GO TO 22
0031                IF ((I.GE.1546.AND.I.LE.1770).OR.(I.GE.1906.AND.I.LE.2490)) GO TO
                   123
0032                IF ((I.GE.1771.AND.I.LE.1905).OR.(I.GE.2491.AND.I.LE.2520).OR.(I.G
                   1E.4612.AND.I.LE.5430)) GO TO 24
0033                IF (I.GE.2521.AND.I.LE.2530) GO TO 25
0034                IF (I.GE.2531.AND.I.LE.2580) GO TO 26
0035                IF(((I.GE.2581.AND.I.LE.2610).OR.(I.GE.2836.AND.I.LE.4611).OR.(I.GE
                   1.5431)) GO TO 27
0036                IF (I.GE.2611.AND.I.LE.2835) GO TO 28
0037          1     CALL FVETS(I,W,C3,TX)
0038          2     CALL FIVAD(I,W,C2,TX)
0039          3     CALL SJSEJ(I,W,C12,TX)
0040          4     CALL LUAP(I,W,C1,TX)
0041          5     CALL FKUL(I,IV,W,IHAZE,TX,SUM7,ALAM)
0042                GO TO 40
0043          6     CALL FVETS(I,W,C3,TX)
0044          7     CALL FIVAD(I,W,C2,TX)
0045                GO TO 4
0046          8     CALL ROJ(I,W,C15,TX)
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          GO TO 6
    9     CALL NHOJ(I,IV,W,C5,TX,SUM5)
          GO TO 8
   10     CALL SUTIT(I,W,C14,TX)
          GO TO 9
   11     CALL PETEP(I,W,C11,SUM11,TX)
          GO TO 10
   12     CALL SUTIT(I,W,C14,TX)
   13     CALL PETEP(I,W,C11,SUM11,TX)
   14     CALL NHOJ(I,IV,W,C5,TX,SUM5)
          GO TO 6
   15     CALL SUSEJ(I,W,C12,TX)
          GO TO 12
   16     CALL SUSEJ(I,W,C12,TX)
          GO TO 13
   17     CALL EOJ(I,W,C15,TX)
          GO TO 13
   18     CALL AEZE(I,W,C13,TX)
          GO TO 14
   19     CALL KEAM(I,W,C4,TX,SUM4)
          GO TO 14
   20     CALL SUSEJ(I,W,C12,TX)
          GO TO 19
   21     CALL SEMAJ(I,IV,W,TX,SUM6)
          GO TO 5
   22     CALL SEMAJ(I,IV,W,TX,SUM6)
          GO TO 7
   23     CALL SEMAJ(I,IV,W,TX,SUM6)
          GO TO 4
   24     CALL SEMAJ(I,IV,W,TX,SUM6)
          GO TO 5
   25     CALL EIVAD(I,W,C2,TX)
          GO TO 24
   26     CALL SESOM(I,W,C8,TX,SUM8)
          GO TO 25
   27     CALL SESOM(I,W,C3,TX,SUM8)
          GO TO 24
   28     CALL LHAP(I,W,C1,TX)
          GO TO 27
   40     RETURN
          END
```

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FORTRAN IV G LEVEL  21              LUAP              DATE = 79218        16/22/49            PAGE 0001

              SUBROUTINE LUAP(I,W,C1,TX)
              DIMENSION C1(2580),TX(1),WS(1),W(1)
        C*************************************************************************
        C
        C     TRANSMITTANCE FOR WATER VAPOR
        C
        C     THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
        C     TRANSMITTANCE TABLE.
        C
        C*************************************************************************
              IF (W(I).LT.1.0E-20) GO TO 5
              IF (I.LE.1170) II=I
              IF (I.GT.1905.AND.I.LE.2490) II=I-135
              IF (I.GT.2610) II=I-255
              WS(I)=ALOG10(W(I))+C1(II)
              TX(I)=EXP(-10**(-1.1619+0.55013*WS(I)))
        5     RETURN
              END
```

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FORTRAN IV G LEVEL  21                DIVAD              DATE = 79218        16/22/49              PAGE 0001

0001                SUBROUTINE DIVAD(I,W,C2,TX)
0002                DIMENSION C2(1575),TX(2),WS(2),W(2)
          C*****************************************************************
          C
          C         TRANSMITTANCE FOR UNIFORMLY MIXED GASES
          C
          C         THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
          C         TRANSMITTANCE TABLE.
          C
          C*****************************************************************
0003                IF (W(2).LT.1.0E-20) GO TO 5
0004                II=I-3)
0005                IF (I.GT.2520) II=I-1005
0006                WS(2)=ALOG10(W(2))+C2(II)
0007                TX(2)=EXP(-10**(-1.1+619+0.55013*WS(2)))
0008          5     RETURN
0009                END
```

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FORTRAN IV G LEVEL  21              EVETS              DATE = 79218         16/22/49              PAGE 0001

 0001                 SUBROUTINE EVETS(I,W,C3,TX)
 0002                 DIMENSION C3(540),TX(3),WS(3),W(3)
               C*******************************************************************
               C
               C      TRANSMITTANCE FOR OZONE
               C
               C      THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
               C      TRANSMITTANCE TABLE.
               C
               C*******************************************************************
 0003                 IF (W(3).LT.1.0E-20) GO TO 5
 0004                 I1=I-45
 0005                 WS(3)=ALOG10(W(3))+C3(I1)
 0006                 TX(3)=1/(1+EXP(-3.08019+2.11127*WS(3)))
 0007          5      RETURN
 0008                 END
```

```
FORTRAN IV G LEVEL  21                  NHOJ                DATE = 79218        16/22/49              PAGE 0001

            SUBROUTINE NHOJ(I,IV,W,C5,TX,SUM5)
      C*****TRANSMITTANCE FOR WATER VAPOR CONTINUM 4 MICRON AND 10 MICRON REGION
            DIMENSION C5(15),TX(5),W(10)
            IF(I.LT.65.OR.I.GT.531) GO TO 2
            IF(I.GT.201) GO TO 1
            TX(5)=(4.18+5578.0*EXP(-7.87E-3*IV))*W(5)
            GO TO 3
      1     IF(I.LT.401) GO TO 2
            XI=(I-401.0)/10.0+1.0
            NH=XI+1.001
            XH=XI-FLOAT(NH)
            TX(5)=C5(NH)
            TX(5)=TX(5)+XH*(C5(NH)-C5(NH-1))
            TX(5)=TX(5)*W(10)
            GO TO 3
      2     TX(5)=0.0
      3     SUM5=TX(5)
            IF (TX(5).EQ.0.0) GO TO 5
            IF (TX(5).LE.0.1) GO TO 4
            IF (TX(5).GT.20.) GO TO 6
            TX(5)=EXP(-TX(5))
            GO TO 7
      4     TX(5)=1.0-TX(5)+0.5*TX(5)*TX(5)
            GO TO 7
      5     TX(5)=1.0
            GO TO 7
      6     TX(5)=0.0
      7     RETURN
            END
```

```
FORTRAN IV G LEVEL  21                 KRAM               DATE = 79218        16/22/49              PAGE 0001

              SUBROUTINE KRAM(I,W,C4,TX,SUM4)
        C*********TRANSMITTANCE FOR NITROGEN CONTINUUM***************************
              DIMENSION C4(133),TX(4),W(4)
              IF (I.LT.307) GO TO 4
              I1=I-346
              TX(4)=C4(I1)*W(4)
              SUM4=TX(4)
              IF (TX(4).EQ.0.0) GO TO 4
              IF (TX(4).LE.0.1) GO TO 3
              IF (TX(4).GT.20.) GO TO 5
              TX(4)=EXP(-TX(4))
              GO TO 6
        3     TX(4)=1.0-TX(4)+0.5*TX(4)*TX(4)
              GO TO 6
        4     TX(4)=1.0
              GO TO 6
        5     TX(4)=0.0
        6     RETURN
              END
```

```
FORTRAN IV G LEVEL  21                SEMAJ              DATE = 79218        16/22/49              PAGE 0001

0001              SUBROUTINE SEMAJ(I,IV,W,TX,SUM6)
            C**********TRANSMITTANCE FOR MOLECULAR SCATTERING ***********************
0002              DIMENSION TX(6),W(6)
0003              V=IV
0004              C6=9.807E-20*(V**4.0117)
0005              TX(6)=C6*W(6)
0006              SUM6=TX(6)
0007              IF (TX(6).EQ.0.0) GO TO 4
0008              IF (TX(6).LE.0.1) GO TO 3
0009              IF (TX(6).GT.20.) GO TO 5
0010              TX(6)=EXP(-TX(6))
0011              GO TO 6
0012        3     TX(6)=1.0-TX(6)+0.5*TX(6)*TX(6)
0013              GO TO 6
0014        4     TX(6)=1.0
0015              GO TO 6
0016        5     TX(6)=0.0
0017        6     RETURN
0018              END
```

```
FORTRAN IV G LEVEL  21                EKUL              DATE = 79218        16/22/49            PAGE 0001

             SUBROUTINE EKUL(I,IV,W,IHAZE,TX,SUM7,ALAM)
      C********* TRANSMITTANCE FOR AEROSOL ****************************************
             COMMON /M06/ VX(45),C7(45),C7A(45)
             DIMENSION TX(10),W(7)
             V=IV
             ALAM=1.0E+4/V
             XX=0.0
             YY=0.0
             IF(IHAZE.EQ.0) GO TO 3
             DO 1 N=1,44
             XD=ALAM-VX(N)
             IF(XD) 2,1,1
      1      CONTINUE
      2      XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)
      3      TX(7)=XX*W(7)
             SUM7=TX(7)
             IF (TX(7).EQ.0.0) GO TO 5
             IF (TX(7).LE.0.1) GO TO 4
             IF (TX(7).GT.20.) GO TO 6
             TX(7)=EXP(-TX(7))
             GO TO 7
      4      TX(7)=1.0-TX(7)+0.5*TX(7)*TX(7)
             GO TO 7
      5      TX(7)=1.0
             GO TO 7
      6      TX(7)=0.0
      7      CONTINUE
             IF(IHAZE.EQ.0) GO TO 12
             YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)
      12     TX(10)=YY*W(7)
             IF (TX(10).EQ.0.0) GO TO 9
             IF (TX(10).LE.0.1) GO TO 8
             IF (TX(10).GT.20.) GO TO 10
             TX(10)=EXP(-TX(10))
             GO TO 11
      8      TX(10)=1.0-TX(10)+0.5*TX(10)*TX(10)
             GO TO 11
      9      TX(10)=1.0
             GO TO 11
      10     TX(10)=0.0
      11     RETURN
             END
```

```
FORTRAN IV G LEVEL  21            SESOM            DATE = 79218        16/22/49            PAGE 0001

               SUBROUTINE SESOM(I,W,C8,TX,SUMB)
      C******** TRANSMITTANCE FOR UV OZONE ************************************
               DIMENSION C8(102),TX(8),W(8)
               AI=I
               IF(I.LE.4611) GO TO 1
               IF(I.GE.5431) GO TO 2
       1       XX=40.0
               XI=(AI-2531.0)/XX+1.0
               L1=1
               L2=53
               GO TO 3
       2       XX=100.0
               XI=(AI-5431.0)/XX+57.0
               L1=57
               L2=102
       3       DO 4  N=L1,L2
               XD=XI-FLOAT(N)
               IF (XD) 6,5,4
       4       CONTINUE
       5       TX(8)=W(8)*C8(N)
               GO TO 8
       6       TX(8)=C8(N)+XD*(C8(N)-C8(N-1))
               TX(8)=W(8)*TX(8)
       8       SUMB=TX(8)
               IF (TX(8).EQ.0.0) GO TO 10
               IF (TX(8).LE.0.1) GO TO 9
               IF (TX(8).GT.20.0) GO TO 11
               TX(8)=EXP(-TX(8))
               GO TO 12
       9       TX(8)=1.0-TX(8)+0.5*TX(8)*TX(8)
               GO TO 12
      10       TX(8)=1.0
               GO TO 12
      11       TX(8)=0.0
      12       RETURN
               END
```

```
FORTRAN IV G LEVEL  21                RETEP              DATE = 79218          16/22/49              PAGE 0001

              SUBROUTINE RETEP(I,W,C11,TX,SUM11)
      C******** TRANSMITTANCE FOR NITRIC ACID*********************************
              DIMENSION C11(44),TX(11),W(11)
              HABS=0.
              IF(I.LT.100.OR.I.GT.278) GO TO 1
              IF(I.GT.116.AND.I.LT.186) GO TO 1
              IF(I.GT.201.AND.I.LT.266) GO TO 1
              IF (I.LE.116) I1=I-100
              IF (I.GE.186.AND.I.LE.201) I1=I-170
              IF (I.GE.266) I1=I-234
              HABS=C11(I1)
      1       CONTINUE
              TX(11)=HABS*W(11)
              SUM11=TX(11)
              IF (TX(11).EQ.0.0) GO TO 6
              IF (TX(11).LE.0.1) GO TO 5
              IF (TX(11).GT.20.) GO TO 7
              TX(11)=EXP(-TX(11))
              GO TO 8
      5       TX(11)=1.0-TX(11)+0.5*TX(11)*TX(11)
              GO TO 8
      6       TX(11)=1.0
              GO TO 8
      7       TX(11)=0.0
      8       RETURN
              END
```

```
FORTRAN IV G LEVEL  21              SUSEJ            DATE = 79218        16/22/49             PAGE 0001

0001             SUBROUTINE SUSEJ(I,W,C12,TX)
0002             COMMON /MOIO/ FS(9),S1(9),S2(9)
0003             DIMENSION C12(115),TX(12),WS(12),W(12)
           C*****************************************************************
           C
           C     THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY SO2 ( PPM READ IN
           C     THE MAIN PROGRAM).
           C
           C*****************************************************************
0004             IF (W(12).LT.1.0E-20) GO TO 5
0005             IF (I.GE.19.AND.I.LE.54) I1=I-18
0006             IF (I.GE.142.AND.I.LE.181) I1=I-104
0007             IF (I.GE.193.AND.I.LE.213) I1=I-116
0008             IF (I.GE.421) I1=I-323
0009             WS(12)=ALOG10(W(12))+C12(I1)
0010             DO 1 J=1,9
0011             IF(WS(12)-FS(J)) 2,2,1
0012       1     CONTINUE
0013       2     TX(12)=EXP(-10**(S1(J)+S2(J)*WS(12)))
0014       5     RETURN
0015             END
```

```
FOPTRAN IV G LEVEL  21                ARZE                DATE = 79218          16/22/49              PAGE 0001

0001              SUBROUTINE ARZE(I,W,C13,TX)
0002              COMMON /M0117 FN0(9),FN1(9),FN2(9)
0003              DIMENSION C13(+3),TX(13),WS(13),W(13)
            C*****************************************************************
            C
            C     THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NO  ( PPM READ IN
            C     THE MAIN PROGRAM).
            C
            C*****************************************************************
0004              II=I-282
0005              IF (W(13).LT.1.0E-20) GO TO 3
0006              WS(13)=ALOG10(W(13))+C13(II)
0007              DO 1 J=1,9
0008              IF (WS(13)-FN0(J)) 2,2,1
0009        1     CONTINUE
0010        2     TX(13)=EXP(-10**(FN1(J)+FN2(J)*WS(13)))
0011        3     RETURN
0012              END
```

```
FORTRAN IV G LEVEL  21                  SUTIT              DATE = 79218        16/22/49              PAGE 0001

0001                  SUBROUTINE SUTIT(I,W,C14,TX)
0002                  COMMON /MD12/ FNH3(9),FH1(9),FH2(9)
0003                  DIMENSION C14(109),TX(14),WS(14),W(14)
            C*****************************************************************
            C
            C         THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NH3 ( PPM READ IN
            C         THE MAIN PROGRAM).
            C
            C*****************************************************************
0004                  I1=I-68
0005                  IF (W(14).LT.1.0E-20) GO TO 3
0006                  WS(14)=ALOG10(W(14))+C14(I1)
0007                  DO 1 J=1,9
0008                  IF (WS(14)-FNH3(J)) 2,2,1
0009        1         CONTINUE
0010        2         TX(14)=EXP(-10**(FH1(J)+FH2(J)*WS(14)))
0011        3         RETURN
0012                  END
```

```
      SUBROUTINE BOJ(I,W,C15,TX)
      COMMON /MO13/ FNO2(9),D1(9),C2(9)
      DIMENSION C15(45),TX(15),WS(15),W(15)
C***********************************************************************
C
C     THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NO2 ( PPM READ IN
C     THE MAIN PROGRAM).
C
C***********************************************************************
      IF (I.LE.106) I1=I-105
      IF (I.GE.239.AND.I.LE.265) I1=I-192
      IF (I.GE.499.AND.I.LE.510) I1=I-425
      IF (W(15).LT.1.0E-20) GO TO 3
      WS(15)=ALOG10(W(15))+C15(I1)
      DO 1 J=1,9
      IF (WS(15)-FNO2(J)) 2,2,1
    1 CONTINUE
    2 TX(15)=EXP(-10**(D1(J)+C2(J)*WS(15)))
    3 RETURN
      END
```

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
1  1  1  0  0  0  0  0  0  0  0       0.0        0.0
               0.0        2.500    65.000     5.000      0.0        0.0
 450.000   455.000     5.000

        HORIZONTAL PATH, ALTITUDE =  0.0   KM,RANGE =  5.000 KM

                 MODEL ATMOSPHERE 1 = TROPICAL

                      HAZE MODEL 1 =  23KM VISUAL RANGE

        FREQUENCY RANGE V1=   450.0 CM-1 TO V2=   455.0 CM-1 FOR DV =   5.0 CM-1   ( 21.98 - 22.22 MICRONS )
```

HORIZONTAL PROFILES

1	0.0	0.182E 01	0.879E 00	0.256E-02	0.695E 00	0.492E-01	0.910E 00	0.100E 01	0.261E-02	0.249E-03	0.255E 00	0.0	0.198E-01
2	1.0	0.114E 01	0.741E 00	0.246E-02	0.571E 00	0.259E-01	0.829E 00	0.440E 00	0.261E-02	0.227E-03	0.164E 00	0.0	0.179E-01
3	2.0	0.738E 00	0.622E 00	0.227E-02	0.467E 00	0.149E-01	0.754E 00	0.190E 00	0.252E-02	0.205E-03	0.112E 00	0.0	0.162E-01
4	3.0	0.338E 00	0.515E 00	0.205E-02	0.376E 00	0.436E-02	0.679E 00	0.798E-01	0.238E-02	0.186E-03	0.513E-01	0.0	0.145E-01
5	4.0	0.143E 00	0.431E 00	0.181E-02	0.306E 00	0.120E-02	0.616E 00	0.422E-01	0.219E-02	0.169E-03	0.233E-01	0.0	0.131E-01
6	5.0	0.883E-01	0.359E 00	0.166E-02	0.248E 00	0.652E-03	0.558E 00	0.318E-01	0.210E-02	0.152E-03	0.158E-01	0.0	0.118E-01
7	6.0	0.451E-01	0.296E 00	0.151E-02	0.199E 00	0.264E-03	0.503E 00	0.224E-01	0.201E-02	0.137E-03	0.874E-02	0.0	0.106E-01
8	7.0	0.224E-01	0.245E 00	0.138E-02	0.159E 00	0.105E-03	0.453E 00	0.208E-01	0.191E-02	0.124E-03	0.485E-02	0.C	0.944E-02
9	8.0	0.107E-01	0.201E 00	0.125E-02	0.127E 00	0.405E-04	0.408E 00	0.215E-01	0.182E-02	0.111E-03	0.261E-02	0.408E-54	0.841E-02
10	9.0	0.459E-02	0.163E 00	0.119E-02	0.999E-01	0.136E-04	0.364E 00	0.206E-01	0.182E-02	0.990E-04	0.124E-02	0.364E-05	0.747E-02
11	10.0	0.171E-02	0.133E 00	0.113E-02	0.789E-01	0.405E-05	0.325E 00	0.201E-01	0.182E-02	0.883E-04	0.528E-03	0.107E-04	0.661E-02
12	11.0	0.516E-03	0.107E 00	0.113E-02	0.616E-01	0.100E-05	0.290E 00	0.188E-01	0.191E-02	0.784E-04	0.184E-03	0.232E-04	0.583E-02
13	12.0	0.161E-03	0.858E-01	0.112E-02	0.476E-01	0.278E-06	0.256E 00	0.197E-01	0.201E-02	0.693E-04	0.656E-04	0.308E-04	0.513E-02
14	13.0	0.426E-04	0.680E-01	0.111E-02	0.365E-01	0.676E-07	0.226E 00	0.182E-01	0.210E-02	0.613E-04	0.204E-04	0.317E-04	0.449E-02
15	14.0	0.209E-04	0.543E-01	0.105E-02	0.281E-01	0.320E-07	0.200E 00	0.179E-01	0.210E-02	0.538E-04	0.120E-04	0.320E-04	0.391E-02
16	15.0	0.138E-04	0.422E-01	0.103E-02	0.210E-01	0.206E-07	0.174E 00	0.165E-01	0.219E-02	0.469E-04	0.929E-05	0.314E-04	0.340E-02
17	16.0	0.101E-04	0.327E-01	0.967E-03	0.157E-01	0.148E-07	0.152E 00	0.160E-01	0.219E-02	0.404E-04	0.832E-05	0.289E-04	0.293E-02
18	17.0	0.765E-05	0.247E-01	0.133E-02	0.113E-01	0.110E-07	0.130E 00	0.158E-01	0.322E-02	0.340E-04	0.660E-05	0.259E-04	0.246E-02
19	18.0	0.580E-05	0.177E-01	0.161E-02	0.780E-02	0.823E-08	0.107E 00	0.153E-01	0.420E-02	0.281E-04	0.431E-05	0.225E-04	0.200E-02
20	19.0	0.483E-05	0.128E-01	0.233E-02	0.540E-02	0.680E-08	0.885E-01	0.128E-01	0.653E-02	0.233E-04	0.312E-05	0.203E-04	0.164E-02
21	20.0	0.379E-05	0.937E-02	0.295E-02	0.377E-02	0.528E-08	0.736E-01	0.943E-02	0.887E-02	0.194E-04	0.214E-05	0.221E-04	0.134E-02
22	21.0	0.368E-05	0.686E-02	0.348E-02	0.265E-02	0.512E-08	0.613E-01	0.684E-02	0.112E-01	0.162E-04	0.182E-05	0.227E-04	0.111E-02
23	22.0	0.316E-05	0.505E-02	0.380E-02	0.187E-02	0.437E-08	0.513E-01	0.514E-02	0.131E-01	0.136E-04	0.138E-05	0.215E-04	0.915E-03
24	23.0	0.290E-05	0.380E-02	0.407E-02	0.135E-02	0.400E-08	0.435E-01	0.394E-02	0.149E-01	0.116E-04	0.118E-05	0.226E-04	0.765E-03
25	24.0	0.279E-05	0.286E-02	0.406E-02	0.977E-03	0.386E-08	0.369E-01	0.312E-02	0.159E-01	0.981E-05	0.106E-05	0.222E-04	0.641E-03
26	25.0	0.270E-05	0.216E-02	0.381E-02	0.708E-03	0.376E-08	0.314E-01	0.263E-02	0.159E-01	0.654E-05	0.959E-06	0.119E-04	0.538E-03
27	30.0	0.726E-06	0.548E-03	0.198E-02	0.148E-03	0.940E-09	0.142E-01	0.791E-03	0.112E-01	0.299E-05	0.163E-06	0.369E-05	0.230E-03
28	35.0	0.115E-06	0.149E-03	0.565E-03	0.334E-04	0.135E-09	0.666E-02	0.208E-03	0.429E-02	0.142E-05	0.211E-07	0.146E-06	0.103E-03
29	40.0	0.239E-07	0.428E-04	0.190E-03	0.809E-05	0.265E-10	0.324E-02	0.548E-04	0.191E-02	0.697E-06	0.330E-08	0.324E-56	0.474E-04
30	45.0	0.577E-08	0.129E-04	0.461E-04	0.206E-05	0.605E-11	0.162E-02	0.144E-04	0.607E-03	0.355E-06	0.610E-09	0.0	0.226E-04
31	50.0	0.108E-08	0.424E-05	0.119E-04	0.579E-06	0.107E-11	0.853E-03	0.381E-05	0.201E-03	0.133E-06	0.989E-10	0.0	0.114E-04
32	70.0	0.235E-11	0.509E-07	0.842E-07	0.364E-08	0.162E-14	0.713E-04	0.196E-07	0.401E-05	0.103E-07	0.477E-12	0.0	0.794E-06
33	100.0	0.150E-15	0.540E-11	0.518E-11	0.104E-12	0.604E-19	0.385E-06	0.696E-11	0.201E-08	0.553E-10	0.230E-16	0.0	0.297E-08
34	******	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FROM POINT: HEIGHT= 0.0 KM,N= 1,NP= 1,REF. INDEX ABOVE & BELOW X= 0.2489E-03 0.0 ,IP= 1

EQUIV. ABSORBER AMOUNTS PER KM AT X= 0.192E 01 0.879E 00 0.256E-02 0.695E 00 0.492E-01 0.910E 00 0.100E 01 0.261E-02

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
450	22.2222	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9331	0.0376
455	21.9780	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9329	0.0376

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
450	22.2222	0.9990	1.0000	1.0000	1.0000	2.5000	0.0000
455	21.9780	0.9948	1.0000	1.0000	1.0000	4.9999	0.0000

INTEGRATED ABSORPTION FROM 450 TO 455 CM-1 = 5.00,AVERAGE TRANSMITTANCE =0.0000
1

FREQUENCY RANGE V1= 550.0 CM-1 TO V2= 555.0 CM-1 FOR DV = 5.0 CM-1 (18.02 - 18.18 MICRONS)

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV+IS) ATM CM
W(1-9)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
550	18.1818	0.0211	0.9365	1.0000	1.0000	1.0000	1.0000	0.9332	0.0343
555	18.0180	0.0232	0.9190	1.0000	1.0000	1.0000	1.0000	0.9324	0.0349

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
550	18.1818	0.9175	1.0000	1.0000	1.0000	2.4577	0.0169
555	18.0180	0.9308	1.0000	1.0000	1.0000	4.9113	0.0185

INTEGRATED ABSORPTION FROM 550 TO 555 CM-1 = 4.91,AVERAGE TRANSMITTANCE =0.0177

1

FREQUENCY RANGE V1= 650.0 CM-1 TO V2= 655.0 CM-1 FOR DV = 5.0 CM-1 (15.27 - 15.38 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-9)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
650	15.3846	0.2465	0.0000	0.9983	1.0000	1.0000	1.0000	0.9337	0.0390
655	15.2672	0.2866	0.0000	0.9979	1.0000	1.0000	1.0000	0.9338	0.0396

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
650	15.3846	1.0000	1.0000	1.0000	0.9996	2.5000	0.0000
655	15.2672	1.0000	1.0000	1.0000	0.9997	5.0000	0.0000

INTEGRATED ABSORPTION FROM 650 TO 655 CM-1 = 5.00,AVERAGE TRANSMITTANCE =0.0000
1

FREQUENCY RANGE V1= 750.0 CM-1 TO V2= 755.0 CM-1 FOR DV = 5.0 CM-1 (13.25 - 13.33 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.399E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
950	10.5263	0.8800	0.9603	0.9994	1.0000	0.1642	1.0000	0.9231	0.0341
955	10.4712	0.8681	0.9612	0.9988	1.0000	0.1692	1.0000	0.9226	0.0347

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
950	10.5263	1.0000	1.0000	0.9212	1.0000	2.2052	0.1179
955	10.4712	1.0000	1.0000	0.8878	1.0000	4.4165	0.1155

INTEGRATED ABSORPTION FROM 950 TO 955 CM-1 = 4.42,AVERAGE TRANSMITTANCE =0.1167
1

FREQUENCY RANGE V1= 1150.0 CM-1 TO V2= 1155.0 CM-1 FOR DV = 5.0 CM-1 (8.66 - 8.70 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-9)=	0.911E 01	0.440E 01	0.129E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.393E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
750	13.3333	0.4889	0.4739	0.9980	1.0000	0.0084	1.0000	0.9361	0.0261
755	13.2450	0.5450	0.5962	0.9983	1.0000	0.0097	1.0000	0.9359	0.0260

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
750	13.3333	1.0000	1.0000	0.9814	0.9994	2.4956	0.0018
755	13.2450	1.0000	1.0000	0.9783	0.9995	4.9884	0.0029

INTEGRATED ABSORPTION FROM 750 TO 755 CM-1 = 4.99,AVERAGE TRANSMITTANCE =0.0023
1

FREQUENCY RANGE V1= 950.0 CM-1 TO V2= 955.0 CM-1 FOR DV = 5.0 CM-1 (10.47 - 10.53 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-9)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
1150	8.6957	0.7275	0.9622	0.9973	1.0000	0.3041	1.0000	0.9055	0.0548
1155	8.6580	0.7094	0.9612	0.9980	1.0000	0.3060	1.0000	0.9373	0.0560

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
1150	8.6957	0.9040	1.0000	0.9788	1.0000	2.0748	0.1701
1155	8.6580	0.8929	1.0000	0.9820	1.0000	4.1606	0.1657

INTEGRATED ASORPTION FROM 1150 TO 1155 CM-1 = 4.16,AVERAGE TRANSMITTANCE =0.1679
1

FREQUENCY RANGE V1= 1350.0 CM-1 TO V2= 1355.0 CM-1 FOR DV = 5.0 CM-1 (7.38 - 7.41 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
1350	7.4074	0.0001	0.6340	1.0000	1.0000	0.3456	1.0000	0.9310	0.0347
1355	7.3801	0.0001	0.6823	1.0000	1.0000	1.0000	1.0000	0.9302	0.0350

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
1350	7.4074	0.2780	1.0000	1.0000	1.0000	2.5000	0.0000
1355	7.3801	0.2728	1.0000	1.0000	1.0000	5.0000	0.0000

INTEGRATED ABSORPTION FROM 1350 TO 1355 CM-1 = 5.00,AVERAGE TRANSMITTANCE =0.0000
1

FREQUENCY RANGE V1= 1850.0 CM-1 TO V2= 1855.0 CM-1 FOR DV = 5.0 CM-1 (5.39 - 5.41 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AER. SOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.530E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
2450	4.0816	0.9922	0.9617	1.0000	0.7665	0.8288	1.0000	0.9212	0.0119
2455	4.0733	0.9914	0.9645	1.0000	0.7827	0.8320	1.0000	0.9211	0.0119

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
2450	4.0816	1.0000	1.0000	1.0000	1.0000	1.1041	0.5584
2455	4.0733	0.9998	1.0000	1.0000	1.0000	2.1705	0.5734

INTEGRATED ABSORPTION FROM 2450 TO 2455 CM-1 = 2.17,AVERAGE TRANSMITTANCE =0.5659
1

FREQUENCY RANGE V1= 3150.0 CM-1 TO V2= 3155.0 CM-1 FOR DV = 5.0 CM-1 (3.17 - 3.17 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.123E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.393E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
1850	5.4054	0.0000	0.9955	0.9999	1.0000	1.0000	1.0000	0.9283	0.0186
1855	5.3908	0.0000	0.9948	0.9999	1.0000	1.0000	1.0000	0.9282	0.0185

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
1850	5.4054	1.0000	0.8961	1.0000	1.0000	2.5000	0.0000
1855	5.3908	1.0000	0.9034	1.0000	1.0000	5.0000	0.0000

INTEGRATED ABSORPTION FROM 1850 TO 1855 CM-1 = 5.00,AVERAGE TRANSMITTANCE =0.0000
1

FREQUENCY RANGE V1= 2450.0 CM-1 TO V2= 2455.0 CM-1 FOR DV = 5.0 CM-1 (4.07 - 4.06 MICRONS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
W(1-8)=	0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

	NITRIC ACID	SO2	NO	NH3	NO2
W(11-15)=	0.0	0.590E-01	0.102E 00	0.953E-01	0.398E-01

FREQ CM-1	WAVELENGTH MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
3150	3.1746	0.4800	0.9190	0.9998	1.0000	1.0000	1.0000	0.9116	0.0231
3155	3.1696	0.5021	0.9373	0.9998	1.0000	1.0000	1.0000	0.9116	0.0233

FREQ CM-1	WAVELENGTH MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	NO2 TRANS	INTEGRATED ABSORPTION	TOTAL TRANS
3150	3.1746	1.0000	1.0000	1.0000	1.0000	1.4951	0.4020
3155	3.1696	1.0000	1.0000	1.0000	1.0000	2.9229	0.4289

INTEGRATED ABSORPTION FROM 3150 TO 3155 CM-1 = 2.92,AVERAGE TRANSMITTANCE =0.4154
0

```
C
C        ADSET   V 1-3
C
C        EVALUATION OF ABSORBER PARAMETERS AND STANDARD EMPIRICAL AND
C        PIECEWISE-ANALYTICAL TRANSMISSION FUNCTIONS
C
C        THIS CODE USES THE SUBROUTINE SIMQ IN SSP LIBRARY
C
C     THIS CODE CONSISTS OF
C        MAIN:  COMPUTATIONS OF BAND PARAMETERS N,M,C'
C               AND EMPIRICAL STANDARD TRANSMISSION FUNCTION
C        NMBC:  COMPUTATION OF NON-MAJOR BANDS' C-VALUES
C        INTPL1:  COMPUTATION OF THE PIECEWISE-ANALYTICAL
C                 STANDARD TRANSMISSION FUNCTION GIVEN BY
C                 TAU = EXP(-10**(A1+A2*X))
C        INTPL2:  COMPUTATION OF THE PIECEWISE-ANALYTICAL
C                 STANDARD TRANSMISSION FUNCTION GIVEN BY
C                 TAU = EXP(-10**(A1+A2*X+A3*X**2))
C        SDTAU:  COMPUTATION OF THE ERROR STANDARD DERIVATIONS
C                BETWEEN PIECEWISE ANALYTICAL STANDARD
C                TRANSMISSION FUNCTION AND THE ORIGINAL DATA
C                USED IN THE MAIN PROGRAMME
C
C      DATA SET-UP
C         1. 1ST CARD   TITLE IN 20A4
C                     (ABSORBER TYPE,ETC)
C         2. 2ND CARD   FOUR CONTROL NUMBERS IN 4I5
C                MAXRPT  MAXIMUN NUMBER OF REPETITION OF
C                          THE COMPUTATION IN MAIN
C                INDX(1)  SUBROUTINE NMBC IS CALLED IF > 0
C                INDX(2)  SUBROUTINE INTPL1 IS CALLED IF > 0
C                INDX(3)  SUBROUTINE INTPL2 IS CALLED IF > 0
C         3. DATA SET FOR MAIN
C                 CONSISTS OF SEVERAL SUBSETS (MAX.6) OF DATA
C                 CORRESPONDING TO INDIVIDUAL MAJOR BANDS
C                 FIRST CARD FOR EACH SUBSET IS A CONTROL CARD WHICH
C                 CONTAINS BAND#, WAVE NUMBER, # OF CUTS AND # OF LEVELS
C                 IN THIS ORDER BY THE FORMAT (I5,F10.3,2I5)
C                 REFER TO THE READ(5,105) AND FORMAT 105 FOR THE
C                 CONTENTS OF EACH CARD.
C                 END OF DATA IS DEFINED BY A BLANK CONTROL CARD
C          4. DATA SET FOR NMBC
C                  INDIVIDUAL DATA FORMAT - SAME AS FOR MAIN
C                  END OF EACH DATA SET FOR A BAND IS MARKED BY
C                  A BLANK CARD
C                  END OF ALL DATA IS MARKED BY -1 (I2) IN ADDITION TO
C                  A BLANK CARD
C                  IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN
C                  THIS SUBROUTINE IS SKIPPED.
C          5. DATA SET FOR INTPL1
C                  FORMATION OF THE DATA IS THE SAME AS THAT  FOR MAIN
C                  DATA (IF SUPPLIED) WILL BE USED FOR S.D. COMPUTATION
C                  ONLY.
C                  IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN THE
C                  S.D. COMPUTATION IS SKIPPED.
C          6. DATA SET FOR INTPL2
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C                 FORMATION OF THE DATA IS THE SAME AS THAT FOR MAIN
C                 IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN
C                 THIS SUBROUTINE IS SKIPPED.
C     NOTE:   DATA SET MUST HAVE A CUT STRUCTURE SUCH THAT EQUAL
C             TRANSMITTANCE DATA ARE GROUPED TOGETHER AND THESE GROUPS
C             ARE QUEUED IN THE DECENDING ORDER IN TAU. THE QUEUING OF
C             THE LEVELS WITHIN EVERY GROUP MUST BE THE SAME.
C
      DIMENSION V(19),A(19,19),X(361),B(19),RI(6,12,10)
      DIMENSION P(10),WWW(12,10),STANDV(12),TSD(6),NDATA(6),INDX(3)
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
     *               AN,AM,CF,ICONST(6),NEL
      COMMON /PARM2/ PRES(6,12,10),TEMP(6,12,10),UGAS(6,12,10),
     *               TAU(6,12),NTC(6),NLV(6)
      CF=1.0
      LOOPCT=1
      WCRIT=2.
      M=0
      READ(5,100) (NAME(I),I=1,20)
  100 FORMAT(20A4)
      READ(5,101) MAXRPT,(INDX(I),I=1,3)
  101 FORMAT(4I5)
C
C        COMPUTATION OF ABSORBER PARAMETERS N, M & C-VALUES IS REPEATED
C         MAXRPT TIMES, WHERE 1 < MAXRPT < 10 IS READ IN BY I5 FORMAT
C         (SUGGESTED VALUE IS 5)
C
C        DATA READ-IN ROUTINE
C
 1000 CONTINUE
      READ(5,102) IC,W,JM,KM
  102 FORMAT(I5,F10.3,2I5)
      IF(IC.LE.0) GO TO 2000
      IF(M.GT.0) GO TO 10
      CALL DATE (MONTH,IDAY,IYEAR)
      WRITE(6,111)MONTH,IDAY,IYEAR
  111 FORMAT(1H1,T60,I4,' / ',I2,' / ',I2,//)
      WRITE(6,200) (NAME(I),I=1,20)
  200 FORMAT(1H ,T25,20A4)
      GO TO 11
   10 CONTINUE
      WRITE(6,201)
  201 FORMAT(1H1)
   11 CONTINUE
      M=M+1
      WN(M)=W
      NTC(M)=JM
      NLV(M)=KM
      WRITE(6,202) M,WN(M),NTC(M),NLV(M)
  202 FORMAT(1H0,T15,'***  BAND',I3,'  (WAVE NUMBER =',F10.3,')  ***',
     * ///,T20,'TOTAL # OF CUTS   =',I3,//,T20,'TOTAL # OF LEVELS =',I3,
     * ///)
      WRITE(6,203)
  203 FORMAT(1H ,T5,'( DATA FORMAT )',//,T9,'GAS#',T15,'WAVE #',T24,
     * 'PRESSURE',T36,'TEMP.',T46,'PPM',T58,'RANGE',T70,'UGAS',T78,
     * 'TRANSM.',/)
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      DO 12 J=1,JM
      WRITE(6,204) J
  204 FORMAT(1H0,T5,'< CUT',I3,' >',/)
      T=0.
      IT=0
      DO 13 K=1,KM
      READ(5,103)  KGAS,FREQ,RPRES,RTEMP,PPM,RANGE,RUGAS,TX
  103 FORMAT(I2,F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F7.4)
      RUGAS=RUGAS/CF
      WRITE(6,205) KGAS,FREQ,RPRES,RTEMP,PPM,RANGE,RUGAS,TX
  205 FORMAT(T10,I2,F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F8.4)
C
C         PRES, TEMP & UGAS ARE CONVERTED TO THE LOG OF THE NORMALIZED
C         VALUES. IF RPRES=0 (INDICATES NO DATA),THEN UGAS(M,J,K) IS SET
C         AT AN IMPOSSIBLE VALUE , ALSO RI(M,J,K) IS SET TO ZERO.
C
      IF(RPRES.GT.0.) GO TO 14
      PRES(M,J,K)=0.
      TEMP(M,J,K)=0.
      UGAS(M,J,K)=10.
      RI(M,J,K)=0.
      GO TO 15
   14 CONTINUE
      PRES(M,J,K)=ALOG10(RPRES/1013.)
      TEMP(M,J,K)=ALOG10(273.15/RTEMP)
      UGAS(M,J,K)=ALOG10(RUGAS)
   15 CONTINUE
C
      T=T+TX
      IT=IT+1
      RI(M,J,K)=1.0
   13 CONTINUE
      TAU(M,J)=T/FLOAT(IT)
   12 CONTINUE
      GO TO 1000
C
C         END OF DATA INPUT
C
C         CONSTANTS USED IN LATER COMPUTATION ARE INITIALIZED
C         FROM 2000 TO 3000.
C         NCUT = MAXIMUM # OF CUTS USED IN COMPUTATION
C         NDIM = DIMENSION OF THE COEFFICIENT MATRIX
C
 2000 CONTINUE
      IF(M.GT.0) GO TO 20
      WRITE(6,206)
  206 FORMAT(1H0,//,T10,'$$$  NO INPUT DATA  $$$')
      STOP
   20 CONTINUE
      NC=M
      CSTD(1)=0.
      NCUT=NTC(1)
      NPTS=NTC(1)*NLV(1)
      IF(NC.LE.1) GO TO 21
      DO 22 I=2,NC
      NCUT=MAX0(NCUT,NTC(I))
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```
      NPTS=NPTS+NTC(I)*NLV(I)
   22 CONTINUE
   21 CONTINUE
      FNC=FLOAT(NC)
      RIT=FLOAT(NPTS)
      DO 23 J=1,NCUT
      TC=0.
      DO 24 M=1,NC
      TC=TC+TAU(M,J)
   24 CONTINUE
      TSTD(J)=TC/FNC
   23 CONTINUE
      NDIM=NC+1+NCUT
C
C*******************************************************************************
C        COMPUTATION OF THE ABSORBER PARAMETERS.
C        THIS LOOP WILL BE REPEATED MAXRPT TIMES.
C
C        FORMATION OF THE NORMAL EQUATION AX = B , A IS SYMMETRIC
C
 3000 CONTINUE
      DO 30 I=1,19
      B(I)=0.
      DO 31 J=1,19
      A(I,J)=0.
   31 CONTINUE
   30 CONTINUE
C
      DO 1 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      DO 2 J=1,JM
      DO 3 K=1,KM
      IF(RI(M,J,K).LT.0.5.) GO TO 3
      DO 4 IC=1,19
      V(IC)=0.
    4 CONTINUE
      V(NDIM-M)=1.
      V(NDIM)=PRES(M,J,K)
      V(NDIM-1)=TEMP(M,J,K)
      VV=-UGAS(M,J,K)
      V(NCUT+1-J)=1.
      DO 5 II=1,NDIM
      DO 6 IJ=1,NDIM
      A(II,IJ)=V(II)*V(IJ)*RI(M,J,K) + A(II,IJ)
    6 CONTINUE
      B(II)=V(II)*VV*RI(M,J,K) + B(II)
    5 CONTINUE
    3 CONTINUE
    2 CONTINUE
    1 CONTINUE
C
C        IF J-TH ROW OF "A" IS ZERO, A(J,J) IS CHANGED TO -1
C         WHICH IS DONE IN ORDER TO MAKE "A" NON-SINGULAR
C         THIS HAPPENS WHEN ALL OF THE DATA FOR BAND J-1 FAIL TO SATISFY
C         THE CRITERION W < WCRIT.  THE BAND J-1 WILL BE IGNORED IF THIS
```

```
            HAPPENS, AND THE C-VALUE FOR BAND J-1 WILL BE COMPUTED
C           SEPARETELY.
C
      ICONST(1)=1
      IF(NC.EQ.1) GO TO 40
      DO 41 M=2,NC
      ICONST(M)=1
      I=NDIM-M
      IF(A(I,I).NE.0.) GO TO 41
      A(I,I)=-1.0
      ICONST(M)=0
   41 CONTINUE
   40 CONTINUE
C
C
      NCOL=0
      DO 42 J=1,NDIM
      DO 43 I=1,NDIM
      NCOL=NCOL+1
      X(NCOL)=A(I,J)
   43 CONTINUE
   42 CONTINUE
C
C           PRINTING OF THE HEADING FOR EACH TRIAL AND THE NORMAL EQUATION
C
      IF(LOOPCT.GT.1) GO TO 50
      WRITE(6,207) MAXRPT,LOOPCT
  207 FORMAT(1H1,T20,'***  ABSORBER PARAMETER COMPUTATION  ***',///,
     * T15,'NOTE:  THE COMPUTATION WILL BE REPEATED MAXRPT =',I2,
     * ' TIMES.',////,T10,'TRIAL #',I1,5X,'(ALL DATA WERE USED)')
      GO TO 51
   50 CONTINUE
      WRITE(6,208) LOOPCT
  208 FORMAT(1H1,T10,'TRIAL #',I1,5X,'(PARTIAL DATA WERE USED WITH',
     * ' CUT-OFF CRITERION :  W < 2 )')
   51 CONTINUE
      WRITE(6,209) NDIM,NDIM
  209 FORMAT(//,1H0,'< NORMAL EQUATION : AX = B >',//,T10,',WHERE THE',
     * ' COEFFICIENT MATRIX A(',I3,' ,',I3,' ) AND THE CONSTANT VECTOR',
     * ' B ARE',//)
      IF(NDIM.LE.17) GO TO 52
      WRITE(6,210) NDIM
  210 FORMAT(1H ,'***  WARNING : DIMENSION OF THE MATRIX IS TOO LARGE',
     * ' (',I3,' ) TO BE PRINTED IN A MATRIX FORM  ***',/)
   52 CONTINUE
      DO 53 I=1,NDIM
      WRITE(6,211) (A(I,J),J=1,NDIM),B(I)
  211 FORMAT(1H ,18F7.3)
   53 CONTINUE
C
C*****      MATRIX INVERSION SUBROUTINE SIMQ IN SSP IS CALLED *************
C
      CALL SIMQ(X,B,NDIM,KS)
C
C           PRINTING OF THE SOLUTION FOR THE NORMAL EQUATION
C
```

```
      IF(KS.EQ.1) WRITE(6,212)
  212 FORMAT(1H0,T10,'WARNING:  THE COEFFICIENT MATRIX IS SINGULAR.')
      AN=B(NDIM)
      AM=B(NDIM-1)
      IF(NC.LE.1) GO TO 54
      DO 55 M=2,NC
      CSTD(M)=B(NDIM-M)
   55 CONTINUE
   54 CONTINUE
      DO 56 J=1,NCUT
      PW(J)=-B(NCUT+1-J)
   56 CONTINUE
      WRITE(6,213) AN,AM,(CSTD(M),M=1,NC)
  213 FORMAT(//,1H0,' < RESULTS >',///,T7,'N',T17,'M',T27,'C1',T37,'C2',
     * T47,'C3',T57,'C4',T67,'C5',T77,'C6',//,2F10.5,6F10.3)
      WRITE(6,214) (PW(I),I=1,NCUT)
  214 FORMAT(/,1H0,T7,'X*1',T17,'X*2',T27,'X*3',T37,'X*4',T47,'X*5',
     * T57,'X*6',T67,'X*7',T77,'X*8',T87,'X*9',T97,'X*10',T107,'X*11',
     * T117,'X*12',//,12F10.3)
      NEL=NPTS-INT(RIT)
      WRITE(6,215) NEL
  215 FORMAT(//,1H0,T4,'# OF ELIMINATED POINTS  =',I5)
C
C        CHECKING OF THE CRITERION ( W < WCRIT ) AND THE COMPUTATION
C        OF C-VALUES FOR THE IGNORED BANDS.
C        RI(M,J,K) = 0 IF  W  IS GREATER THAN OR EQUAL TO WCRIT
C        RI(M,J,K) = 1 IF  W  IS LESS THAN WCRIT
C
      RIT=0.
      DO 60 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      CAVG=0.0
      DO 61 J=1,JM
      DO 62 K=1,KM
      W=AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
      IF(W.GE.WCRIT) RI(M,J,K)=0.
      RIT=RIT+RI(M,J,K)
      CAVG=CAVG+(PW(J)-W)
   62 CONTINUE
   61 CONTINUE
      IF(ICONST(M).EQ.1) GO TO 60
      CSTD(M)=CAVG/FLOAT(JM*KM)
      WRITE(6,216) M,M,M,CSTD(M)
  216 FORMAT(///,1H ,T7,'** WARNING **',T25,'NO DATA FOR BAND',I2,
     * ' SATISFIES THE CRITERION ( W < 2 ).',//,T25,'THE C',I1,
     * ' VALUE IS SEPARATELY COMPUTED BY AVERAGING.',//,T30,'C',I1,
     * ' =',F10.3)
   60 CONTINUE
C
C        COMPUTATIONS OF STANDARD DEVIATIONS IN X
C
      NGDATA=0
      GTSD=0.
      ICST=NC
      DO 70 M=1,NC
```

```
      JM=NTC(M)
      KM=NLV(M)
      NDATA(M)=0
      TSD(M)=0.
      WRITE(6,201)
      WRITE(6,202) M,WN(M),NTC(M),NLV(M)
      WRITE(6,217) AN,AM,M,CSTD(M)
  217 FORMAT(1H ,T10,'N  =',F10.5,//,T10,'M  =',F10.5,//,T10,'C',I1,
     * ' =',F10.5)
      WRITE(6,218)
  218 FORMAT(//,1H0,T7,'RECOMPUTED X-VALUES AND STANDARD DEVIATIONS',
     * ' IN X-VALUES',/,1H0,T2,'CUT',T11,'TAU',T20,'X*',T30,'X1',T39,
     * 'X2',T48,'X3',T57,'X4',T66,'X5',T75,'X6',T84,'X7',T93,'X8',
     * T102,'X9',T111,'X10',T121,'CUTWISE-SD',/)
C
C        COMPUTATION OF THE CUTWISE STANDARD DEVIATIONS IN X
C
      DO 71 J=1,JM
      DN=0.
      WW=0.
      DO 72 K=1,KM
      P(K)=CSTD(M)+AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
      WWW(J,K)=(PW(J)-P(K))**2*RI(M,J,K)
      WW=WW+WWW(J,K)
      DN=DN+RI(M,J,K)
   72 CONTINUE
      WW=SQRT(WW/DN)
      NDATA(M)=NDATA(M)+IFIX(DN)
      WRITE(6,219) J,TAU(M,J),PW(J),(P(K),K=1,KM)
  219 FORMAT(1H ,I5,F9.3,F9.4,1X,10F9.4)
      WRITE(6,220) WW
  220 FORMAT(1H+,T121,F10.5)
   71 CONTINUE
C
C        COMPUTATION OF THE LEVELWISE STANDARD DEVIATIONS IN X
C
      DO 73 K=1,KM
      WW=0.
      DN=0.
      DO 74 J=1,JM
      WW=WW+WWW(J,K)
      DN=DN+RI(M,J,K)
   74 CONTINUE
      TSD(M)=TSD(M)+WW
      STANDV(K)=SQRT(WW/DN)
   73 CONTINUE
      WRITE(6,221) (STANDV(K),K=1,KM)
  221 FORMAT(1H0,T4,'LEVELWISE-SD :',T26,10F9.5)
      NGDATA=NGDATA+NDATA(M)*ICONST(M)
      GTSD=GTSD+TSD(M)*FLOAT(ICONST(M))
      ICST=ICST-ICONST(M)
      TSD(M)=SQRT(TSD(M)/FLOAT(NDATA(M)))
      WRITE(6,222) TSD(M)
  222 FORMAT(//,1H0,T4,'TOTAL STANDARD DEVIATION FOR THIS BAND  :',
     * F15.6)
   70 CONTINUE
```

```
C
C
C        PRINTOUT OF THE SUMMARY.
C        ALL VITAL INFORMATIONS ARE PRINTED OUT HERE.
C
C
      GTSD=SQRT(GTSD/FLOAT(NGDATA))
      WRITE(6,223) LOOPCT,AN,AM
  223 FORMAT(1H1,T15,'***  SUMMARY OF THE ABSORBER PARAMETER',
     * ' COMPUTATION FOR TRIAL #',I2,'  ***',///,T20,
     * 'PRESSURE EXPONENT     N =',F10.5,//,T20,
     * 'TEMPERATURE EXPONENT M =',F10.5,///,T5,'CASE #',3X,
     * 'WAVE NUMBER',5X,'C-VALUE',5X,'TOTAL # OF DATA',3X,
     * 'CASEWISE S.D. IN P')
      WRITE(6,224) (M,WN(M),CSTD(M),NDATA(M),TSD(M),M=1,NC)
  224 FORMAT(1H0,T6,I3,6X,F9.2,5X,F8.3,10X,I3,12X,F12.6)
      WRITE(6,225) NGDATA,NEL,GTSD
  225 FORMAT(//,1H0,T15,'GRAND TOTAL # OF DATA =',I5,//,T15,'# OF',
     * ' ELIMINATED DATA =',I5,//,T15,'GLOBAL STANDARD DEVIATION IN P',
     * ' =',F12.6,//)
      IF(ICST.LE.0) GO TO 75
      DO 76 M=1,NC
      IF(ICONST(M).EQ.1) GO TO 76
      WRITE(6,226) M
  226 FORMAT(1H ,T15,'NOTE:  THE BAND',I3,' IS NOT INCLUDED IN THE',
     * ' FINAL STANDARD DEVIATION')
   76 CONTINUE
   75 CONTINUE
      WRITE(6,227) LOOPCT,(TSTD(J),PW(J),J=1,NCUT)
  227 FORMAT(///,1H0,T15,'***  STANDARD EMPIRICAL TRANSMISSION',
     * ' FUNCTION FOR TRIAL #',I2,'  ***',///,T20,'TAU',T35,'X*',/,
     * (1H0,T17,F7.3,T30,F8.4))
C
C
      IF(RIT.GT.0.) GO TO 80
C
C        IF NO INPUT DATA SATISFIES THE CRITERION, THE COMPUTATION IS
C        TERMINATED. THE MOST RECENT RESULTS WILL BE USED IN THE SEQUAL.
C
      WRITE(6,228)
  228 FORMAT(1H1,//,T15,'$$$  NO INPUT DATA SATISFIES THE CRITERION OF',
     * ' ( W < 2 )  $$$',//,T15,'$$$  THE COMPUTATION FOR THIS STEP IS',
     * ' TERMINATED  $$$')
      GO TO 4000
   80 CONTINUE
      LOOPCT=LOOPCT+1
      IF(LOOPCT.GT.MAXRPT) GO TO 4000
      GO TO 3000
C
 4000 CONTINUE
C
C        SUBROUTINE COMPUTATIONS FOLLOW
C
      IF(INDX(1).LE.0) GO TO 90
C
      CALL NMBC
```

```
C
   90 CONTINUE
      IF(INDX(2).LE.0) GO TO 91
C
      CALL INTPL1
C
   91 CONTINUE
      IF(INDX(3).LE.0) GO TO 92
C
      CALL INTPL2
C
   92 CONTINUE
      STOP
      END
      SUBROUTINE NMBC
C
C        COMPUTATION OF C'-VALUES FOR NON-MAJOR BANDS
C
      DIMENSION B(15),CS(15),FS(15)
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
     *               AN,AM,CF,ICONST(6),NEL
      WRITE(6,5) (NAME(I),I=1,20)
    5 FORMAT(1H1,T15,20A4)
      WRITE(6,10)
   10 FORMAT(1H0,T15,' *** CALCULATION OF THE SPECTRAL PARAMETERS',
     * 'FOR NON-MAJOR BANDS ***'///)
      DF=1.E30
   11 CONTINUE
      NFREQ=0
   12 CONTINUE
      C=0.
      I=0
   15 CONTINUE
      READ(5,20) KGAS,FREQ,P,T,UGAS,TX
   20 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
      IF(KGAS.EQ.0) GO TO 25
      IF (KGAS.LT.0) GO TO 35
C
C        THE FOLLOWING IF-STATEMENT IS INSERTED TO DETECT
C        AND TO IGNORE THE INVALID DATA POINTS.
C
      IF(UGAS.GE.DF) GO TO 15
      I=I+1
      WX=FREQ
      UGAS=UGAS/CF
      C=C+(PW(I)-AN*ALOG10(P/1013.)-AM*ALOG10(273.15/T)-ALOG10(UGAS))
      GO TO 15
   25 C=C/FLOAT(I)
      NFREQ=NFREQ+1
      CS(NFREQ)=C
      FS(NFREQ)=WX
      DO 27 M=1,NC
      IF(ABS(WX-WN(M)).LE.0.1) CS(NFREQ)=CSTD(M)
   27 CONTINUE
      IF(NFREQ.EQ.10) GO TO 30
      GO TO 12
```

```
   30 CONTINUE
      WRITE(6,31) (FS(K),K=1,NFREQ)
   31 FORMAT(1H0,2X,'WAVE NUMBER',2X,10F11.0)
      WRITE(6,32) (CS(K),K=1,NFREQ)
   32 FORMAT(1H0,5X,'C VALUES',2X,10F11.3//)
      GO TO 11
   35 CONTINUE
      IF(NFREQ.EQ.0) GO TO 40
      WRITE(6,31) (FS(K),K=1,NFREQ)
      WRITE(6,32) (CS(K),K=1,NFREQ)
   40 CONTINUE
      RETURN
      END
C
      SUBROUTINE INTPL1
C
C        COMPUTATION OF THE STANDARD PIECEWISE-ANALYTICAL TRANSMISSION
C        FUNCTION
C
C        VERSION 1 - 1   ** A3(I) = 0 **
C        TAU = EXP(-10**( A1(I)+A2(I)*X ))
C
      DIMENSION SDCUT(15),ICUT(15),SDTCUT(15),ITCUT(15)
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
     *               AN,AM,CF,ICONST(6),NEL
      COMMON /PARM3/ A1(11),A2(11),A3(11)
      SSD=0.
      ITOTAL=0
      IM=NCUT-1
      JM=NCUT-2
C
C
C        COMPUTATION OF THE COEFFICIENTS A1(I), A2(I) AND A3(I)
C
      CTX1=ALOG10(-ALOG(TSTD(1)))
      DO 50 I=1,IM
      PDIF=PW(I)-PW(I+1)
      CTX2=ALOG10(-ALOG(TSTD(I+1)))
      A1(I)=(PW(I)*CTX2-PW(I+1)*CTX1)/PDIF
      A2(I)=(CTX1-CTX2)/PDIF
      A3(I)=0.
      CTX1=CTX2
C
      SDTCUT(I)=0.
   50 ITCUT(I)=0
C
C        THE FIRST AND LAST VALUES OF TSTD AND PW ARE CHANGED
C        FOR THE TABLE OUTPUT. TRUE VALUES ARE TEMPORARY STORED
C        IN THE RESERVE.
C
      TRES1=TSTD(1)
      TRES2=TSTD(NCUT)
      PWRES1=PW(1)
      PWRES2=PW(NCUT)
      TSTD(1)=1.0
      TSTD(NCUT)=0.0
```

```
      PW(1)=-1.E70
      PW(NCUT)=1.E70
C
C        PRINT OUT OF THE RESULTS
C
      WRITE(6,2) (NAME(I),I=1,20)
    2 FORMAT(1H1,T25,20A4,'//,T15,'PIECEWISE-ANALYTICAL STANDARD',
     * 'TRANSMISSION FUNCTION',//,T20,'TAU(X) =',
     * ' EXP(-10**( A1 + A2*X ) )',///,T15,'DATA:',T23,'FROM ( TAU  ,',
     * 'X-VALUE) TO (  TAU  ,X-VALUE)  WITH  (  A1   ,    A2  )')
      WRITE(6,3) (TSTD(I),PW(I),TSTD(I+1),PW(I+1),A1(I),A2(I),I=1,IM)
    3 FORMAT(1H0,T28,'(',F6.3,' ,',F7.3,')      (',F6.3,' ,',F7.3,')',T74,
     * '(',F7.4,',',F7.4,')')
      WRITE(6,4) (I,WN(I),CSTD(I),I=1,NC)
    4 FORMAT(1H0,//,T15,'ABSORPTION BANDS:',T40,
     * '#  WAVENUMBER   C-VALUE'/(1H0,T39,I2,5X,F7.1,F11.5))
C
C        CHECK IF ANY DATA IS AVAILABLE FOR S.D. COMPUTATION
C        DATA FORMAT IS THE SAME AS THAT FOR MAIN PROGRAMME
C        ONE CONTROL CARD IS READ-IN FIRST FOR BRANCHING
C            IFQ >  0   DATA SET FOLLOWS, READ-IN DATA
C            IFQ =  0   END OF DATA, GO TO THE FINAL PRINTING
C
      READ(5,11,END=42) FQ,IFQ
   11 FORMAT(5X,F10.3,T41,I4)
      IF(IFQ.GT.0) GO TO 18
   42 WRITE(6,41)
   41 FORMAT(///,1H0,T5,'$$$  NO DATA FOR STANDARD DEVIATION COMPUTATION
     *  $$$')
      GO TO 40
    8 READ(5,11,END=30) FQ,IFQ
      IF(IFQ.LE.0) GO TO 30
   18 CONTINUE
      ST=0.
      DO 51 I=1,IM
      SDCUT(I)=0.
   51 ICUT(I)=0
      CLOG=100.
      DO 52 I=1,NC
   52 IF(ABS(FQ-WN(I)).LT.1.) CLOG=CSTD(I)
      IF(CLOG.LT.99.) GO TO 13
C
C        THE READ-IN WAVENUMBER DOES NOT MATCH THE MAJOR BAND
C        WAVENUMBER (WN(I)).THE DATA IN THIS BAND ARE IGNORED.
C
      WRITE(6,12) FQ
   12 FORMAT(1H0,T10,'** ERROR IN WAVENUMBER **',
     * '      (READ-IN WAVENUMBER =',F10.5,' )')
      DO 61 IDUM=1,IFQ
      READ(5,60) DUMMY
   60 FORMAT(F1.0)
   61 CONTINUE
      GO TO 8
C
C        VALID DATA INPUTS,READ-IN OF THE DATA AND STAND RD
C        DEVIATION COMPUTATION ARE PERFORMED SIMULTANEOUS Y.
```

```
C
   13 CONTINUE
      WRITE(6,17) FQ
   17 FORMAT(1H1,T15,'( WAVE NUMBER =',F8.1,' )',///,6X,'WAVEN.',3X,
     * 'PRESS.',4X,'TEMP.',7X,'U',8X,'TRANSM.  -  T(COMP)  =   DIFF',6X,
     * 'DIFF**2',4X,'X-VALUE',/)
      DO 9 M=1,NDATA
      READ(5,10) KGAS,FQ,PRES,TEMP,UG,TX
   10 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
      UG=UG/CF
      X=CLOG+AN*ALOG10(PRES/1013.)+AM*ALOG10(273.15/TEMP)+ALOG10(UG)
      DO 14 J=1,JM
      IF(X.LE.PW(J+1)) GO TO 15
   14 CONTINUE
      J=IM
C
   15 TC=EXP(-10**(A1(J)+A2(J)*X))
C
      D=TX-TC
      SD=D*D
      ST=ST+SD
      SDCUT(J)=SDCUT(J)+SD
      ICUT(J)=ICUT(J)+1
      WRITE(6,16) FQ,PRES,TEMP,UG,TX,TC,D,SD,X
   16 FORMAT(1H ,3X,F8.1,F10.2,F9.2,E13.4,F9.4,F12.4,F13.6,E12.3,F9.3)
    9 CONTINUE
C
C         END OF DATA READ-IN FOR THIS BAND.
C         TOTAL STANDARD DEVIATIONS ARE COMPUTED AND PRINTED.
C
   20 SSD=SSD+ST
      ITOTAL=ITOTAL+IFQ
      ST=SQRT(ST/FLOAT(IFQ))
      DO 21 I=1,IM
      SDTCUT(I)=SDTCUT(I)+SDCUT(I)
      ITCUT(I)=ITCUT(I)+ICUT(I)
   21 SDCUT(I)=SQRT(SDCUT(I)/FLOAT(ICUT(I)))
      WRITE(6,22) (I,TSTD(I),TSTD(I+1),ICUT(I),SDCUT(I),I=1,IM)
   22 FORMAT(1H0,///,T10,'CUTWISE STANDARD DEVIATION',//,T15,'#',T20,
     * '( FROM,  TO )  ',T40,'# OF DATA',T53,'CUTWISE SD',//,(T14,I2,
     * T20,'(',F5.2,',',F5.2,')',T43,I4,T52,F10.6,/))
      WRITE(6,23) IFQ,ST
   23 FORMAT(1H0,T10,'TOTAL # OF DATA FOR THIS BAND  =',I5,9X,
     * ' STANDARD DEVIATION =',F12.6,//)
      GO TO 8
C
C         END OF THE STANDARD DEVIATION COMPUTATION FOR ALL DATA.
C         GRAND TOTAL STANDARD DEVIATION IS COMPUTED AND PRINTED OUT
C         TOGETHER WITH VITAL INFORMATIONS.
C
   30 SSD=SQRT(SSD/FLOAT(ITOTAL))
      DO 31 I=1,IM
   31 SDTCUT(I)=SQRT(SDTCUT(I)/FLOAT(ITCUT(I)))
      WRITE(6,32) (I,TSTD(I),PW(I),TSTD(I+1),PW(I+1),A1(I),A2(I),
     * ITCUT(I),SDTCUT(I),I=1,IM)
   32 FORMAT(1H1,T20,'***  PIECEWISE-ANALYTICAL STANDARD TRANSMISSION',
```

```
     * ' FUNCTION  ***',///,T10,'TOTAL CUTWISE STANDARD DEVIATION',//,
     * T15,'CURVE #',3X,'FROM (  TAU  ,X-VALUE) TO (  TAU  ,X-VALUE)',
     * '  WITH  (   A1   ,   A2  )',3X,'# OF DATA',4X,'CUTWISE SD',//,
     * (T18,I2,T30,'(',F6.3,' ,',F7.3,')    (',F6.3,' ,',F7.3,')',T76,
     * '(',F7.4,',',F7.4,')',7X,I3,5X,F10.6,/))
      WRITE(6,33) ITOTAL,SSD
   33 FORMAT(1H0,T10,'GLOBAL RESULTS',//,T15,'TOTAL NUMBER OF DATA',
     * ' USED',I5,//,T15,'GLOBAL STANDARD DEVIATION',F12.6)
C
   40 CONTINUE
C
C        END OF ALL COMPUTATION.
C        RESERVED TRUE VALUES OF THE FIRST AND LAST TSTD
C        AND PW ARE RETURNED.
C
      TSTD(1)=TRES1
      TSTD(NCUT)=TRES2
      PW(1)=PWRES1
      PW(NCUT)=PWRES2
C
      CALL SDTAU
C
      RETURN
      END
       SUBROUTINE INTPL2
C
C         COMPUTATION OF THE PIECEWISE-ANALYTICAL STANDARD TRANSMISSION
C         FUNCTION
C
C         VERSION 2 - 1
C         TAU=EXP(-10**(A1+A2*X+A3*X**2))
C
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
     *               AN,AM,CF,ICONST(6),NEL
      COMMON /PARM3/ A1(11),A2(11),A3(11)
      DIMENSION T(10),TD(6,74),PD(6,74),JI(6,10),
     * SDK(7),SDE(7,9),SUME(2,9),DE(6,9)
      NWC=0
      K=0
      READ(5,2,END=80) FREQ,MAXDAT
      IF(MAXDAT.GT.0) GO TO 3
   80 CONTINUE
      WRITE(6,99)
   99 FORMAT(///,1H0,T5,'$$$  NO DATA FOR STANDARD DEVIATION COMPUTATION
     *  $$$')
      GO TO 77
    1 CONTINUE
      READ(5,2,END=21) FREQ,MAXDAT
    2 FORMAT(5X,F10.5,T41,I4)
      IF(MAXDAT.EQ.0) GO TO 21
    3 CLOG=1.E 10
      DO 5 L=1,NC
      IF(ABS(FREQ-WN(L)).LE. .01)  CLOG=CSTD(L)
    5 CONTINUE
      IF(ABS(CLOG-1.E10).GE..01) GO TO 9
      WRITE(6,100) FREQ
```

```
100 FORMAT('1',///////,' ERROR IN INPUT DATA ; WAVE NUMBER ',F10.3,
   * ' NOT USED IN COMPUTATION OF CONSTANTS.')
     DO 6 J=1,MAXDAT
     READ(5,101) KGAS,FREQ,PRES,TEMP,PPM,RANGE,UGAS,TX
   6 CONTINUE
     GO TO 1
   9 CONTINUE
     K=K+1
     NWC=NWC+1
     JI(K,1)=0
     JI(K,NCUT)=MAXDAT
     J=2
     DO 20 I=1,MAXDAT
     READ(5,101) KGAS,FREQ,PRES,TEMP,PPM,RANGE,UGAS,TX
 101 FORMAT(I2,F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F7.4)
     TD(K,I)=TX
     PD(K,I)= AN *ALOG10(PRES/1013.)+ AM *ALOG10(273.15/TEMP)+ALOG10
    * (UGAS/CF)+CLOG
     IF(TD(K,I).GE.TSTD(J)) GO TO 20
     IF(J.EQ.NCUT) GO TO 20
     JI(K,J)=I-1
     J=J+1
  20 CONTINUE
     GO TO 1
  21 CONTINUE
     IF(NWC.LE.0) RETURN
     DO 30 J=1,NCUT
     T(J)=ALOG10(-ALOG(TSTD(J)))
  30 CONTINUE
     SUMT=0.
     DT=0.0
     NCC=NCUT-1
     DO 45 I=1,NCC
     SA=0.
     TA=0.
     UA=0.
     DO 41 K=1,NWC
     SUME(K,I)=0.0
     M=JI(K,I)+1
     N=JI(K,I+1)
     DO 40 J=M,N
        TC=ALOG10(-ALOG(TD(K,J)))
     SA=SA+ TC  *PW(I)*PW(I+1)*(PD(K,J)-PW(I))*(PD(K,J)-PW(I+1))
     TA=TA+((PD(K,J)-PW(I))*(PD(K,J)-PW(I+1))*((PD(K,J)**2)*(PW(I+1)
    * *T(I)-PW(I)*T(I+1))+PD(K,J)*((PW(I)**2)*T(I+1)-(PW(I+1)**2)*T(I)
    * )))/(PW(I)-PW(I+1))
     UA=UA+((PD(K,J)-PW(I))*(PD(K,J)-PW(I+1)))**2
  40 CONTINUE
  41 CONTINUE
     A1(I)=(SA-TA)/UA
     A3(I)=(T(I)-T(I+1))/(PW(I+1)*(PW(I)-PW(I+1)))-(T(I)-A1(I))/(PW(I)*
    * PW(I+1))
     A2(I)=(T(I)-T(I+1))/(PW(I)-PW(I+1))-A3(I)*(PW(I)+PW(I+1))
     DI=0.
     SUMI=0.
     DO 44 K=1,NWC
```

```
      M=JI(K,I)+1
      N=JI(K,I+1)
      DE(K,I)=FLOAT(1+N-M)
      DO 43 J=M,N
      SUME(K,I)=SUME(K,I)+(TD(K,J)-EXP(-10.**(A3(I)*PD(K,J)*PD(K,J)+
     *  A2(I)*PD(K,J)+A1(I))))**2
   43 CONTINUE
      SDE(K,I)=SQRT(SUME(K,I)/DE(K,I))
      SUMI=SUMI+SUME(K,I)*FLOAT(ICONST(K))
      DI=DI+DE(K,I)*FLOAT(ICONST(K))
   44 CONTINUE
      SUMT=SUMT+SUMI
      DT=DT+DI
      SDE(NWC+1,I)=SQRT(SUMI/DI)
   45 CONTINUE
      DO 51 K=1,NWC
      SUMK=0.0
      DK=0.0
      DO 50 I=1,NCC
      SUMK=SUMK+SUME(K,I)
      DK=DK+DE(K,I)
   50 CONTINUE
      SDK(K)=SQRT(SUMK/DK)
   51 CONTINUE
      SDK(NWC+1)=SQRT(SUMT/DT)
      DUM1=PW(1)
      DUM2=PW(NCUT)
      DUM3=TSTD(1)
      DUM4=TSTD(NCUT)
      PW(1)=-1000000.
      PW(NCUT)=1000000.
      TSTD(1)=1.0
      TSTD(NCUT)=0.0
      DO 60 K=1,NWC
      WRITE(6,102)(NAME(J),J=1,20),WN(K),NCC,(I,TSTD(I),TSTD(I+1),PW(I),
     * PW(I+1),A1(I),A2(I),A3(I),SDE(K,I),I=1,NCC)
  102 FORMAT  ('1',/,35X,'RENDITION OF EMPIRICAL TRANSMITTANCE FUNCTION
     *FOR : '//,20A4,//,40X,'WAVE  NUMBER :',F15.4,////,20X,'THE TRANSMI
     *SSION CURVE IS DIVIDED INTO',I3,'  SEPARATE CURVES.',/20X,'EACH CU
     *RVE IS EXPRESSED BY A FUNCTION OF THE FORM  " TAU = EXP(-10**(A3*P
     #*P+A2*P+A1)) ".'/,20X,                        'THE  FUNCTION  COEFFI
     *CIENTS AND RESULTING STANDARD DEVIATION  FOR EACH CURVE ARE AS FOL
     *LOWS:',////22X,'TAU',20X,'P',24X,'A1',13X,'A2',13X,'A3',11X,'STAND
     *ARD DEVIATION',///, (5X,'CURVE #',I3,3X,'(',F4.2,'-',F4.2,')',5X,
     *'(',F9.5,'-',F9.5,')',5X,3F15.6, 6X,F15.6 /))
      WRITE(6,401) SDK(K)
  401 FORMAT(1X,//,87X,'TOTAL STANDARD DEVIATION',F15.6)
   60 CONTINUE
      K=K+1
      WRITE(6,104)  (NAME(J),J=1,20),NCC,  (I,TSTD(I),TSTD(I+1),PW(I),
     * PW(I+1),A1(I),A2(I),A3(I),SDE(K,I),I=1,NCC)
  104 FORMAT  ('1',/,35X,'RENDITION OF EMPIRICAL TRANSMITTANCE FUNCTION
     *FOR : '//,20A4,//,40X,'TOTAL PROFILE AVERAGED OVER ALL WAVE NUMBER
     *S'                                         ,////,20X,'THE TRANSMI
     *SSION CURVE IS DIVIDED INTO',I3,'  SEPARATE CURVES.',/20X,'EACH CU
     *RVE IS EXPRESSED BY A FUNCTION OF THE FORM  " TAU = EXP(-10**(A3*P
```

```
     #*P+A2*P+A1)) ".'/,20X,                          'THE  FUNCTION  COEFFI
     *CIENTS AND RESULTING STANDARD DEVIATION  FOR EACH CURVE ARE AS FOL
     *LOWS:',////22X,'TAU',20X,'P',24X,'A1',13X,'A2',13X,'A3',11X,'STAND
     *ARD DEVIATION',///, (5X,'CURVE #',I3,3X,'(',F4.2,'-',F4.2,')',5X,
     *'(',F9.5,'-',F9.5,')',5X,3F15.6, 6X,F15.6 /))
      WRITE(6,402) SDK(K)
  402 FORMAT(1X,//,81X,'GRAND TOTAL STANDARD DEVIATION',F15.6)
C     WRITE(7,201)(A1(I),A2(I),A3(I),I=1,NCC)
C 201 FORMAT(3F10.6)
C
      IDT=IFIX(DT)
      WRITE(6,225)IDT,NEL,SDK(K)
  225 FORMAT(//,1H0,T15,'GRAND TOTAL # OF DATA =',I5,//,T15,'# OF',
     * ' ELIMINATED DATA =',I5,//,T15,'GLOBAL STANDARD DEVIATION IN',
     * ' TAU =',F12.6,//)
      DO 76 M=1,NWC
      IF(ICONST(M).EQ.1) GO TO 76
      WRITE(6,226) M
  226 FORMAT(1H ,T15,'NOTE:  THE BAND',I3,' IS NOT INCLUDED IN THE',
     * ' FINAL STANDARD DEVIATION')
   76 CONTINUE
      PW(1)=DUM1
      PW(NCUT)=DUM2
      TSTD(1)=DUM3
      TSTD(NCUT)=DUM4
C
      CALL SDTAU
C
   77 CONTINUE
      RETURN
      END
      SUBROUTINE SDTAU
C
C        COMPUTATIONS OF STANDARD DEVIATIONS IN TAU USING THE ORIGINAL
C        DATA USED IN MAIN
C
      DIMENSION NDATA(6),TSD(6),WWW(12,10),STANDV(12),P(10),T(10)
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
     *               AN,AM,CF,ICONST(6),NEL
      COMMON /PARM2/ PRES(6,12,10),TEMP(6,12,10),UGAS(6,12,10),
     *               TAU(6,12),NTC(6),NLV(6)
      COMMON /PARM3/ A1(11),A2(11),A3(11)
C
      NGDATA=0
      GTSD=0.
      ICST=NC
      DO 70 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      NDATA(M)=JM*KM
      NGDATA=NGDATA+NDATA(M)*ICONST(M)
      TSD(M)=0.
      WRITE(6,214)
  214 FORMAT('1',/////,45X,'RECOMPUTATION OF TAU',/////)
      IF(M.GT.1) GO TO 77
       WRITE(6,215)
```

```
  215 FORMAT(20X,'A TAU VALUE , T , IS RECOMPUTED FOR THE ORIGIONAL DATA
     * USING THE PIECEWISE-ANALITICAL TRANSMISSION FUNCTION.'//20X,
     * 'STANDARD DEVIATIONS BETWEEN THE ACTUAL TAU AND THE RECOMPUTED',
     * ' TAU VALUES ARE COMPUTED.'////)
   77 CONTINUE
      WRITE(6,202) M,WN(M),NTC(M),NLV(M)
  202 FORMAT(1H0,T15,'***  CASE',I3,'  (WAVE NUMBER =',F10.3,')  ***',
     * ///,T20,'TOTAL # OF CUTS   =',I3,//,T20,'TOTAL # OF LEVELS =',I3,
     * ///)
      WRITE(6,216) AN,AM,M,CSTD(M)
  216 FORMAT(10X,'N  =',F10.5,//10X,'M  =',F10.5,//,10X,'C',I1,' =',
     * F10.5,////)
      WRITE(6,217)
  217 FORMAT(//,1H0,T7,'RECOMPUTED TAU AND STANDARD DEVIATIONS',
     * ' IN TAU ',/,1H0,T2,'CUT',T11,'TAU',T20,'X*',T30,'X1',T39,
     * 'X2',T48,'X3',T57,'X4',T66,'X5',T75,'X6',T84,'X7',T93,'X8',
     * T102,'X9',T111,'X10',T121,'CUTWISE-SD',/)
C
C        COMPUTATION OF THE CUTWISE STANDARD DEVIATIONS IN X
C
      DO 71 J=1,JM
      WW=0.
      DO 72 K=1,KM
      P(K)=CSTD(M)+AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
      IM=JM-1
      DO 75 I=1,IM
      IF(PW(I+1).GT.P(K)) GO TO 76
   75 CONTINUE
      I=IM
   76 CONTINUE
      T(K)=EXP(-10**(A3(I)*P(K)*P(K)+A2(I)*P(K)+A1(I)))
      WWW(J,K)=(TAU(M,J)-T(K))**2
      WW=WW+WWW(J,K)
   72 CONTINUE
      WW=SQRT(WW/FLOAT(KM))
      WRITE(6,218) J,PW(J),TAU(M,J),(T(K),K=1,KM)
  218 FORMAT(1H ,I5,F9.4,F9.4,1X,10F9.4)
      WRITE(6,219) WW
  219 FORMAT(1H+,T121,F10.5)
   71 CONTINUE
C
C        COMPUTATION OF THE LEVELWISE STANDARD DEVIATIONS IN X
C
      DO 73 K=1,KM
      WW=0.
      DO 74 J=1,JM
      WW=WW+WWW(J,K)
   74 CONTINUE
      TSD(M)=TSD(M)+WW
      STANDV(K)=SQRT(WW/FLOAT(JM))
   73 CONTINUE
      WRITE(6,220) (STANDV(K),K=1,KM)
  220 FORMAT(1H0,T4,'LEVELWISE-SD :',T26,10F9.5)
      GTSD=GTSD+TSD(M)*FLOAT(ICONST(M))
      ICST=ICST-ICONST(M)
      TSD(M)=SQRT(TSD(M)/FLOAT(NDATA(M)))
```

```
      WRITE(6,221) TSD(M)
  221 FORMAT(1H0,//,T15,'TOTAL STANDARD DEVIATION FOR THIS CASE  :',
     * F15.6)
   70 CONTINUE
      GTSD=SQRT(GTSD/FLOAT(NGDATA))
      WRITE(6,223) AN,AM
  223 FORMAT('1',T15,'***  SUMMARY OF THE TRANSMITTANCE RECOMPUTATION  *
     * **',///,T20,'PRESSURE EXPONENT    N =',F10.5,//,T20,
     * 'TEMPERATURE EXPONENT M =',F10.5,///,T5,'CASE #',3X,
     * 'WAVE NUMBER',5X,'C-VALUE',5X,'TOTAL # OF DATA',3X,
     * 'CASEWISE S.D. IN TAU')
      WRITE(6,224) (M,WN(M),CSTD(M),NDATA(M),TSD(M),M=1,NC)
  224 FORMAT(1H0,T6,I3,6X,F9.2,5X,F8.3,10X,I3,12X,F12.6)
      WRITE(6,225) NGDATA,NEL,GTSD
  225 FORMAT(//,1H0,T15,'GRAND TOTAL # OF DATA =',I5,//,T15,'# OF',
     * ' ELIMINATED DATA =',I5,//,T15,'GLOBAL STANDARD DEVIATION IN',
     * ' TAU =',F12.6,//)
      IF(ICST.LE.0) RETURN
      DO 78 M=1,NC
      IF(ICONST(M).EQ.1) GO TO 78
      WRITE(6,226) M
  226 FORMAT(1H ,T15,'NOTE:  THE BAND',I3,' IS NOT INCLUDED IN THE',
     * ' FINAL STANDARD DEVIATION')
   78 CONTINUE
      RETURN
      END
```

```
C
C******  COMPUTER CODE  SIMMIN  ******
C        VERSION ( 6 - 3 ) TRACE GASSES
C
C        COMPUTATION OF ABSORBER PARAMETERS AND ANALYTICAL STANDARD
C        TRANSMISSION FUNCTION
C
C        THIS CODE USES THE SUBROUTINE FMCG IN SSP LIBRARY
C
C     THIS CODE CONSISTS OF
C        MAIN:  DATA READ-IN AND CONTROL OF COMPUTATION
C        FUNCT:  COMPUTATION OF THE COST AND ITS DERIVATIVES
C        TITLE:  PRINTING OF HEADINGS AND INITIAL CONDITIONS
C        PRINT1:  PRINTOUT OF RESULTS AND COMPUTATION/PRINTING OF S.D.S
C        NMBC:  COMPUTATION OF NON-MAJOR BANDS' C-VALUES
C
C     DATA SET-UP
C        1. INITIAL GUESSES  X(I)  (9 CARDS WITH T12,F10.7)
C            X(1)=A1, X(2)=A2, X(3)=A3, X(4)=N, X(5)=M, X(5+I)=LOG(C(I))
C            (NEED DUMMY INPUTS FOR PROBLEMS WITH DIMENSION < 9)
C        2. SIGNAL VARIABLES  S(I)  (9 CARDS WITH T12,F10.7)
C            S(I) = 0  ...  X(I) IS KEPT CONSTANT
C            S(I) = 1  ...  X(I) IS VARIED
C            (NEED DUMMY INPUTS FOR PROBLEMS WITH DIMENSION < 9)
C        3. COMMENT CARD  (20A4)  FOR TITLE AND ABSORBER TYPE ETC.
C        4. DATA SETS (MAX. 4 SETS)  -  ONE FOR EACH ABSORPTION BAND
C            EACH SET CONSISTS OF
C               1ST(CONTROL) CARD: WAVENUMBER, # OF DATA AND COMMENTS
C                                  (SEE FORMAT 101)
C               DATA CARDS: P, T, U, TAU ETC.
C                                  (SEE FORMAT 102)
C            (TOTAL # OF DATA SHOULD NOT EXCEED 900)
C        5. BLANK CARD  -  FOR THE TERMINATION OF DATA INPUT FOR MAIN
C        6. DATA SETS FOR NMBC  -  ONE FOR EACH ABSORPTION BAND
C            EACH SET CONSISTS OF
C               DATA CARDS:  SAME AS MAIN
C               FINAL CARD:  BLANK
C            TERMINATION   A CONTROL CARD WITH -1 IN FIRST TWO COLUMNS
C                          THIS COMES AFTER THE FINAL BLANK CARD
C            (IF NO DATA BUT A BLANK CARD IS SUPPLIED, NMBC IS SKIPPED)
C
      DIMENSION X(9),G(9),Y(9),H(72),WN(4)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
      COMMON /PARM3/ P(900),T(900),U(900),L(20)
      COMMON /PARM4/ P0,T0,NDIM,ID(5,9)
      EXTERNAL FUNCT
C
C        CONSTANTS
      P0=1.013E+03
      T0=273.15
      CF=2.69E+19
      N=9
      V=0.
      IC=0
      MAXNC=4
```

```
C
C        DATA INPUT
C
      READ(5,100) (X(I),I=1,N)
      READ(5,100) (S(I),I=1,N)
  100 FORMAT (T12,F10.7)
C
C        COMMENT CARD (THIS INCLUDES THE ABSORBER TYPE)
      READ(5,500) (L(I),I=1,20)
  500 FORMAT(20A4)
C
C        NC = # OF MAJOR ABSORPTION BANDS
C        ND(1)=0, ND(2)=N1, ND(3)=N1+N2, ND(4)=N1+N2+N3, ...
C        WHERE N1, N2, N3, ... ARE #S OF DATA IN BANDS 1, 2, 3, ...
C        ND(NC+1)= TOTAL # OF DATA
C
      NC=0
      ND(1)=0
      DO 10 M=1,MAXNC
      READ(5,101) WN(M),IX,(ID(NC+1,I),I=1,9)
  101 FORMAT(5X,F10.3,T41,I4,9A4)
      IF(IX.LE.0) GO TO 11
      NC=NC+1
      IM=ND(NC)+1
      IN=ND(NC)+IX
      ND(NC+1)=IN
      DO 12 I=IM,IN
      READ(5,102) P(I),T(I),U(I),TAU(I)
  102 FORMAT (12X,E11.4,F9.3,24X,E11.4,F7.4)
      U(I)=U(I)/CF
C
C        DATA ARE CONVERTED TO THE LOG OF THE NORMALIZED VALUES
C
      PLOG(I)=ALOG10(P(I)/P0)
      TLOG(I)=ALOG10(T0/T(I))
      ULOG(I)=ALOG10(U(I))
C
   12 CONTINUE
   10 CONTINUE
   11 CONTINUE
C
C        END OF DATA INPUT
C
      IF(NC.GT.0) GO TO 13
      WRITE(6,110)
  110 FORMAT (1H0,'ERROR IN DATA INPUT')
      GO TO 1000
   13 CONTINUE
C
      NDIM=0
      N=5+NC
      DO 14 I=1,N
      IF(S(I).NE.0.) NDIM=NDIM+1
   14 CONTINUE
      DO 15 I=1,NC
      RW(I)=FLOAT(ND(NC+1))/(FLOAT(ND(I+1)-ND(I))*FLOAT(NC))
```

```
      RW(I)=1.0
   15 CONTINUE
C
      DO 16 I=1,N
      Y(I)=X(I)
   16 CONTINUE
C
      EST=1.E-6
      EPS=1.E-6
      LIMIT=1
      IER=0
C
C************* FMCG SEARCH *********************** START ****************
C
      CALL FMCG(FUNCT,N,X,V,G,EST,EPS,LIMIT,IER,H)
C
C************* FMCG SEARCH ***********************  END  ****************
C
      CALL TITLE(N,Y,LIMIT,EPS)
C
      CALL PRINT1(N,X,V,G,IER)
C
      CALL NMBC(X,L,NC,WN,CF,P0,T0)
C
 1000 CONTINUE
      STOP
      END
      SUBROUTINE FUNCT(N,X,V,G)
C
C        COMPUTATION OF THE FUNCTION VALUE AND DERIVATIVES
C
C          (DOUBLE EXPONENTIAL FUNCTION)
C
      DIMENSION X(9),G(9),F(9)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
C
      IC=IC+1
      V=0.
      DO 20 K=1,N
      G(K)=0.
   20 CONTINUE
C
      DO 21 J=1,NC
      JJ=J+5
      SQER=0.
      DO 22 L=1,5
      F(L)=0.
   22 CONTINUE
      F(JJ)=0.
      IM=ND(J)+1
      IN=ND(J+1)
      DO 23 I=IM,IN
      W1=X(JJ)+X(4)*PLOG(I)+X(5)*TLOG(I)+ULOG(I)
      R=X(1)+X(2)*W1+X(3)*W1*W1
      R=10.**R
```

```
      IF(R.LE.70.) GO TO 24
      TC=0.
      GO TO 25
   24 CONTINUE
      TC=EXP(-R)
   25 CONTINUE
      E=TAU(I)-TC
      R=R*E*TC
      SQER=SQER+E**2
      F(1)=F(1)+R
      F(2)=F(2)+R*W1
      F(3)=F(3)+R*W1*W1
      R=R*(X(2)+2.*X(3)*W1)
      F(4)=F(4)+R*PLOG(I)
      F(5)=F(5)+R*TLOG(I)
      F(JJ)=F(JJ)+R
   23 CONTINUE
      V=V+SQER*RW(J)
      DO 26 K=1,5
      G(K)=G(K)+F(K)*RW(J)
   26 CONTINUE
      G(JJ)=F(JJ)*RW(J)
   21 CONTINUE
C
      DO 27 I=1,N
      G(I)=4.60517*G(I)*S(I)
   27 CONTINUE
C
      RETURN
      END
      SUBROUTINE TITLE(N,X,LIMIT,EPS)
C
C        PRINTING OF THE TITLE AND INITIAL VALUES
C
      DIMENSION X(9),L(4)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM4/ PO,TO,NDIM,ID(5,9)
C
      DO 40 I=1,NC
      L(I)=ND(I+1)-ND(I)
   40 CONTINUE
C
      CALL DATE (MONTH,IDAY,IYEAR)
      WRITE(6,111)MONTH,IDAY,IYEAR
  111 FORMAT(1H1,T60,I4,' / ',I2,' / ',I2,/)
      WRITE(6,400) NC,NDIM
  400 FORMAT (1H ,T14,'*** SIMULTANEOUS PARAMETER EVALUATION ***',///,
     * ' PARAMETERS  :  ( N , M , A1 , A2 , A3 , C(I), I=1,',I2,' )',
     * 8X,'( DIMENSION =',I3,' )',///,' DATA  :')
      WRITE(6,401) ((ID(K,J),J=1,9),L(K),K=1,NC)
  401 FORMAT(1H+,T11,'(',9A4,' )',5X,'# OF POINTS =',I5,//)
C
      WRITE(6,402) ND(NC+1),PO,TO,LIMIT,EPS
  402 FORMAT (1H+,T51,'TOTAL # OF DATA =',I5,///,
     * ' FUNCTION  :  TAU ( W )  = EXP ( -10 ** ( A1 + A2 * W +',
     * ' A3 * W**2 + A4 * W**3 ) )',//,T15,'WHERE, ',
```

```
     * ' W = LOG(C) + LOG( U * (P/PO)**N * (TO/T)**M )   ',
     * ',  A4 = 0.',///,
     * ' CONSTANTS  :  PO =',F8.2,7X,'TO =',F8.2,7X,
     * 'LIMIT =',I5,7X,'EPS =',1PE10.1,/)
C
      IF(NC.EQ.1) WRITE(6,403) X(1),X(6),X(2),X(3),X(4),X(5)
      IF(NC.EQ.2) WRITE(6,404) X(1),X(6),RW(1),X(2),X(7),RW(2),X(3),
     *                         X(4),X(5)
      IF(NC.EQ.3) WRITE(6,405) X(1),X(6),RW(1),X(2);X(7),RW(2),X(3),
     *                         X(8),RW(3),X(4),X(5)
      IF(NC.EQ.4) WRITE(6,406) X(1),X(6),RW(1),X(2),X(7),RW(2),X(3),
     *                         X(8),RW(3),X(4),X(9),RW(4),X(5)
  403 FORMAT (1HO,'INITIAL VALUES  :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
     * F12.7,//,T22,'A2 =',F12.7,//,T22,'A3 =',F12.7,//,T22,'N  =',
     * F12.7,//,T22,'M  =',F12.7,/)
  404 FORMAT (1HO,'INITIAL VALUES  :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
     * F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A2 =',F12.7,9X,
     * 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A3 =',
     * F12.7,//,T22,'N  =',F12.7,//,T22,'M  =',F12.7,/)
  405 FORMAT (1HO,'INITIAL VALUES  :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
     * F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A2 =',F12.7,9X,
     * 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A3 =',
     * F12.7,9X,'LOG(C3) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,
     * 'N  =',F12.7,//,T22,'M  =',F12.7,/)
  406 FORMAT (1HO,'INITIAL VALUES  :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
     * F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A2 =',F12.7,9X,
     * 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,'A3 =',
     * F12.7,9X,'LOG(C3) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,T22,
     * 'N  =',F12.7,9X,'LOG(C4) =',F12.7,4X,'( WEIGHT =',F8.4,' )',//,
     * T22,'M  =',F12.7,/)
C
      RETURN
      END
      SUBROUTINE PRINT1(N,X,V,G,IER)
C
C        PRINTING OF THE RESULTS AND COMPUTATION/PRINTING OF ERRORS
C        AND STANDARD DEVIATIONS
C
      DIMENSION X(9),G(9),E(900),PD(900),TC(900),W(900)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
      COMMON /PARM3/ P(900),T(900),U(900),L(20)
      COMMON /PARM4/ PO,TO,NDIM,ID(5,9)
      EQUIVALENCE (E,PLOG),(PD,TLOG),(TC,ULOG)
C
C        EQUIVALENCE IS FOR SPACE CONSERVATION
C
      IT=0
      TTD=0.
      TV=0.
      V=SQRT(V/FLOAT(ND(NC+1)))
C
      WRITE(6,510) IER,IC,(X(I),G(I),I=1,5)
  510 FORMAT (1HO,'** RESULTS OF COMPUTATION  :   IER =',I3,4X,
     * 'SUBROUTINE FUNCT WAS CALLED',I6,' TIMES  **',
     * ///,' FINAL VALUES AND GRADIENTS  :',
```

```
     * T35,'A1      =',F12.7,T65,'D/D(A1)       =',E15.6,//,
     * T35,'A2      =',F12.7,T65,'D/D(A2)       =',E15.6,//,
     * T35,'A3      =',F12.7,T65,'D/D(A3)       =',E15.6,//,
     * T35,'N       =',F12.7,T65,'D/D(N)        =',E15.6,//,
     * T35,'M       =',F12.7,T65,'D/D(M)        =',E15.6)
       WRITE(6,511) (I,X(I+5),I,G(I+5),I=1,NC)
   511 FORMAT(1H0,T35,'LOG(C',I1,')=',F12.7,T65,'D/D(LOG(C',I1,'))=',
     * E15.6)
       WRITE(6,512) V
   512 FORMAT(/,1H0,'FINAL STANDARD DEVIATION  :',F15.7)
C
       WRITE(6,513) (L(I),I=1,20)
   513 FORMAT(1H0,T5,'( COMMENT : ',20A4,' )')
C
       DO 50 J=1,NC
       JJ=J+5
       V=0.
       TD=0.
       IM=ND(J)+1
       IN=ND(J+1)
       K=ND(J+1)-ND(J)
       RK=FLOAT(K)
C
       DO 51 I=IM,IN
       W(I)=X(JJ)+X(4)*PLOG(I)+X(5)*TLOG(I)+ULOG(I)
       R=10.**(X(1)+X(2)*W(I)+X(3)*W(I)**2)
       IF(R.LE.70) GO TO 52
       TC(I)=0.
       GO TO 53
    52 CONTINUE
       TC(I)=EXP(-R)
    53 CONTINUE
       E(I)=TAU(I)-TC(I)
       PD(I)=100.*E(I)/TAU(I)
       TD=TD+ABS(E(I))
       V=V+E(I)**2
    51 CONTINUE
C
       TTD=TTD+TD
       TV=TV+V
       TD=TD/RK
       V=V/RK
       SF=SQRT(V)
       WRITE(6,514) (ID(J,I),I=1,9),K,(X(I),I=1,5),J,X(JJ),TD,V,SF
   514 FORMAT (1H1,T15,'ACTUAL/COMPUTED TRANSMITTANCES',////,
     * T10,'DATA  :',9A4,5X,'# OF POINTS =',I4,////,T10,
     * 'A1 =',F12.7,8X,'A2 =',F12.7,8X,'A3 =',F12.7,//,T10,'N  =',F12.7,
     * 8X,'M  =',F12.7,8X,'LOG(C',I1,') =',F12.7,////,
     * T15,'AVERAGE DISCREPANCY =',F12.7,//,
     * T15,'MEAN SQUARE ERROR   =',F12.7,//,
     * T15,'STANDARD DEVIATION  =',F12.7,////,
     * T5,'#',T11,'U =',T26,'P =',T36,'T =',T46,'X =',T56,'ACTUAL',
     * T65,'COMPUTED',T76,'DIFFERENCE',T90,'% DIFF.',/)
       WRITE(6,515) (I,U(I),P(I),T(I),W(I),TAU(I),TC(I),E(I),PD(I),
     *              I=IM,IN)
   515 FORMAT (1H ,I5,T10,E11.4,T24,F8.2,T34,F8.2,T43,F9.4,T53,F9.4,T63,
```

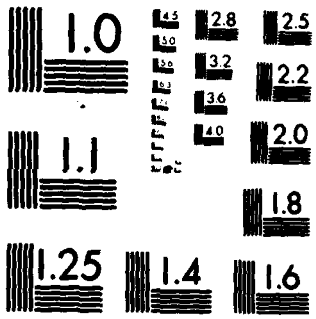
```
     * F9.4,T74,F11.6,T87,F10.4)
   50 CONTINUE
C
      FK=FLOAT(ND(NC+1))
      TTD=TTD/FK
      TV=TV/FK
      TSD=SQRT(TV)
      WRITE(6,516) ND(NC+1),TTD,TV,TSD
  516 FORMAT (1H1,///,T10,'TOTAL # OF POINTS USED          =',I6,///,T10,
     * 'GLOBAL AVERAGE DISCREPANCY    =',F12.7,///,T10,
     * 'GLOBAL MEAN SQUARE ERROR      =',F12.7,///,T10,
     * 'GLOBAL STANDARD DEVIATION     =',F12.7)
      RETURN
      END
      SUBROUTINE NMBC(X,NAME,NC,WN,CF,PO,TO)
C
C        COMPUTATION OF THE C'-VALUES FOR NON-MAJOR BANDS
C
      DIMENSION X(9),NAME(20),WN(4)
      DIMENSION CS(10),FS(10)
      DF=1.E30
      SGN=1.
      IF(X(3).LT.0.) SGN=-1.
C
C        IF THE QUADRATIC TERM IS TOO SMALL, THEN IT WILL BE IGNORED
C
      SMI=-2.*X(3)/X(2)
      IF(ABS(SMI).LE.1.E-6) GO TO 50
      SYM=1./SMI
   50 CONTINUE
C
      WRITE(6.5)(NAME(I),I=1,20)
   5  FORMAT(1H1,T15,20A4)
      WRITE(6,10)
   10 FORMAT(1H0,T15,' *** CALCULATION OF THE SPECTRAL PARAMETER FOR',
     * ' NON-MAJOR BANDS ***',///)
C
   11 CONTINUE
      NFREQ=0
   12 CONTINUE
      C=0.
      I=0
   15 CONTINUE
      READ(5,20,END=40) KGAS,FREQ,P,T,UGAS,TX
   20 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
      IF(KGAS.EQ.0) GO TO 25
      IF(KGAS.LT.0) GO TO 35
      IF(UGAS.GE.DF) GO TO 15
C
      I=I+1
      WX=FREQ
      UGAS=UGAS/CF
      IF(SMI.LE.1.E-6) GO TO 51
C
C        CASE 1  QUADRATIC TERM IS LARGE AND USED
C
```

AD-A081 789 TEXAS UNIV AT EL PASO SCHELLENGER RESEARCH LABS F/G 7/4
COMPUTERIZED METHOD FOR THE GENERATION OF MOLECULAR TRANSMITTAN--ETC(U)
DEC 79 J H PIERLUISSI, K TOMIYAMA DAAG29-79-C-0067
UNCLASSIFIED FR1-79-UA-72 ARO-16641.1-GS NL

3 of 3

END
DATE FILMED
4 80
DTIC

END
DATE FILMED
4 80
DTIC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2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

```
      XS=SYM+SGN*ABS(SQRT(X(2)**2-4.*X(3)*(X(1)-ALOG10(-ALOG(TX))))
     *   /(2.*X(3)))
      GO TO 52
   51 CONTINUE
C
C        CASE 2  QUADRATIC TERM IS SMALL AND IGNORED
C
      XS=(ALOG10(-ALOG(TX))-X(1))/X(2)
   52 CONTINUE
      XC=X(4)*ALOG10(P/PO)+X(5)*ALOG10(TO/T)+ALOG10(UGAS)
      C=C+(XS-XC)
      GO TO 15
C
   25 C=C/FLOAT(I)
      NFREQ=NFREQ+1
      CS(NFREQ)=C
      FS(NFREQ)=WX
      DO 27 M=1,NC
      IF(ABS(WX-WN(M)).LE.0.1) CS(NFREQ)=X(5+M)
   27 CONTINUE
      IF(NFREQ.EQ.10) GO TO 30
      GO TO 12
   30 CONTINUE
      WRITE(6,31)(FS(K),K=1,NFREQ)
   31 FORMAT(1H0,2X,'WAVE NUMBER',2X,10F11.0)
      WRITE(6,32)(CS(K),K=1,NFREQ)
   32 FORMAT(1H0,5X,'C VALUES',2X,10F11.3//)
      GO TO 11
C
   35 CONTINUE
      IF(NFREQ.EQ.0) GO TO 40
      WRITE(6,31)(FS(K),K=1,NFREQ)
      WRITE(6,32)(CS(K),K=1,NFREQ)
   40 CONTINUE
      RETURN
      END
```